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OFFSHORE TESTING OF BOOMS AND SKIMMERS

a report to

ENVIRONMENT CANADA
ENVIRONMENTAL EMERGENCIES TECHNOLOGY DIVISION
OTTAWA, ONTARIO

and

UNITED STATES MINERALS MANAGEMENT SERVICE
RESTON, VIRGINIA

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S.L. ROSS ENVIRONMENTAL RESEARCH LIMITED
OTTAWA, ONTARIO

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ABSTRACT

On September 24, 1987 about 25 nautical miles east of St. John's, Newfoundland combined offshore oil spill boom and skimmer trials were conducted. The trials involved the release of 68 m^3 (18,000 gal)[1] of a crude oil that had been modified by the addition of small amounts of petroleum wax to resemble a typical Grand Banks crude oil. Winds on the test day increased from Beaufort 4 in the morning to Beaufort 5 by evening; the sea state consequently increased from 2 to 4. A 1.5 to 2 m swell (occasionally as high as 4 m) was running.

The RO–BOOM and Vikoma Ocean Pack both proved capable of containing the waxy oil in these seas. The RO–BOOM was prone to oil splashover at the juncture between flotation sections at higher (0.6 knot) relative boom/water velocities while the Vikoma Ocean Pack was prone to oil dispersion losses from small breaking waves created at the junction of the air and water chambers. The Vikoma Ocean Pack was deployed and retrieved faster and easier than the RO–BOOM. The RO–BOOM ~~seems~~ was considered as being slightly more durable for long–term offshore deployment than the Vikoma Ocean Pack. Both booms contained the oil equally well at relative boom/water velocities less than 0.5 m/s (1 knot).

~~Although~~ the objectives were met, for a variety of reasons the testing of all the ~~skimmers~~ did not ~~provide~~ sufficient data for a ~~quantitative–comparison–of~~ their efficiency for ~~use on spills of waxy crude oils with and without Elastol~~ addition. The Framo ACW–400 recovered 11.6 m^3 (3065 gal) of fluid (5 m^3 (1320 gal) of free water and 6.6 m^3 (1745 gal) of emulsified oil of which 2.5 m^3 (660 gal) was water) at an average fluid recovery rate of 39 m^3/hr (172 gal/min) with an average oil recovery efficiency of 35%. The Heavy Oil Skimmer was unsuccessful in recovering the waxy oil prior to the addition of Elastol. Based on one short test of the Heavy Oil Skimmer, prior to its discharge hose failing, it recovered Elastol–treated fluid at an average rate of 11 m^3/hr (48 gal/min) with an oil recovery efficiency of 35%. The

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1. in this report gallons refer to U.S. gallons (1 m^3 = 264 U.S. gal)

GT-185 recovered 9.4 m^3 (2485 gal) of fluid (containing no free water and 5 m^3 (1320 gal) of emulsified water) treated with Elastol at an average fluid recovery rate of 19 m^3/hr (85 gal/min) with an average oil recovery efficiency of 46%.

Further controlled condition testing of the skimmers with waxy and viscous oils is recommended as is further evaluation of Elastol as a skimming aid.

The objectives of the exercise were met in that the performance of the RO and Vikoma booms were compared in conditions approaching the maximum for deployment into the sea and wind. First loss speeds were not determined. For the skimmers, a direct comparison of the HOS and Framo models is not possible because of the addition of elastol but the inability of the HOS to pick up oil before the addition of elastol was noted. Similarly, the suspicion that the Framo was acting as a weir skimmer when it collected the oil before the addition of elastol is important. The GT 185 skimmer was not intended to be used in the exercise and the data obtained is a bonus to the exercise results. The same may be said for the data obtained from the use of elastol.

RESUME

ACKNOWLEDGEMENTS

The author of this report was Ian Buist. The Scientific Authorities for the study were Harry Whittaker of Environment Canada and Ed Tennyson of the United States Minerals Management Service. Funding for the study was provided by Environment Canada, the United States' Minerals Management Service and the Canadian Coast Guard. The assistance of the project officer and staff of the U.S. Environmental Protection Agency's Oil and Hazardous Materials Environmental Test Tank was appreciated.

The author gratefully acknowledges the support provided by Canadian Coast Guard Headquarters (particularly Ed Gauthier), Newfoundland Region (particularly Bill Ryan and Wayne Halley) and Maritimes Region (particularly Rod Stright, Blair Macmillan, Joe Stevens and Ray Carpenter).

The invaluable contribution of the Captains, officers and crews of the CCGS Sir Humphrey Gilbert, CCGS Grenfell, M/V Terra Nova Sea, M/V Triumph Sea and M/V Beinir is also gratefully acknowledged.

Stephen Potter of S.L. Ross Environmental Research Limited, David Dickins of D.F. Dickins Associates Limited, and Francine Laperriere of EETD also contributed to the report. The assistance of Gord Pelly of Environment Canada, Newfoundland Region in obtaining an Ocean Dumping permit is gratefully acknowledged.

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1.0 INTRODUCTION

These offshore trials of oil spill containment and recovery equipment came about in order to meet several needs identified by various agencies. Foremost was the desire to find out whether or not offshore containment and recovery equipment presently stockpiled by the Canadian Coast Guard was suitable for use on spills of oils typical of the waxy crude oils discovered on the Grand Banks. These oils exhibit atypical spill behaviour (S.L. Ross and DMER 1987) and may not be amenable to recovery with conventional oleophilic or weir-type skimmers (S.L. Ross and Hatfield 1986). As well, the operating characteristics of the RO-BOOM and Vikoma Ocean Pack boom were to be compared to determine whether or not one best suited the needs of Coast Guard. In addition there was a desire to field test a novel skimmer developed for the Coast Guard for heavy, viscous oils (Canpolar 1986) on waxy crude oil. Coincidentally, the Oil and Hazardous Materials Environmental Test Tank (OHMSETT) Interagency Technical Committee (OITC) had a need to verify at sea, with oil, a boom testing protocol intended to correlate a boom's ability to contain oil with it's seakeeping ability. If successful this protocol would preclude the need for most offshore testing of booms with oil. Trials with a specially instrumented boom had been conducted in the OHMSETT tank with oil and offshore without oil; these trials were to be the final component of the test program: tests offshore with and without oil.

~~As a result of~~ After several years of planning by an inter-agency task force composed of representatives of Canadian and U.S. government departments the trials were undertaken

1.1 OBJECTIVES

The objectives of the offshore trials were to document and quantify:

* the sea-keeping and waxy oil containment capabilities of the Vikoma Ocean Pack and RO-BOOM in seas representative of Grand Banks conditions;

* the waxy oil recovery capabilities of the Framo ACW−400 type skimmer and the experimental Heavy Oil Skimmer; and
* the sea−keeping and oil retention capabilities of a specially instrumented offshore oil boom in seas representative of offshore conditions.

1.2 REPORT CONTENTS

This report documents the methodology, results, conclusions and recommendations arising from the study pertaining to the first two objectives noted above. A separate report is being written on the final objective of the study by OHMSETT staff (McKowan and Borst 1987).

Section 2.0 of this report documents the site selection, test planning and methodology for this study. Section 3.0 contains the results and a discussion of the results pertaining to boom and skimmer performance. Section 4.0 covers the fate and behaviour of the slick. Section 5 completes the report with the conclusions and recommendations arising from the study.

Much of the raw data is contained in appendices. Several hundred aerial and surface photographs and slides and several hours of aerial and surface videotape are available at Environment Canada for viewing.

2.0 TEST PLANNING, SITE SELECTION AND TEST METHODS

2.1 TEST PLANNING

Many months of planning were devoted to the study by an inter–agency steering committee composed of representatives of both Canadian and U.S. government organizations ~~departments~~. The structure and organization of the team put together by the steering committee is illustrated in Figure 1. The test protocol developed by the team for the trials may be found in Appendix 1.

The general experimental plan was as follows. The OHMSETT instrumented boom would be deployed first and monitored for one hour without oil. Once the next boom was set (see Figure 2) and the oil had been discharged into the OHMSETT instrumented boom, readings would be taken for one hour in a relative current (i.e., tow speed) of about 0.25 m/s (1/2 knot). After this the two boats would speed up until significant entrainment losses occurred (at about 0.5 m/s = 1 knot). One tow vessel on the OHMSETT instrumented boom would then drop back into the mouth of the RO–BOOM and let go of its end of the instrumented boom thus allowing the oil to drift back into the RO–BOOM positioned astern. The Vikoma Ocean Pack boom would be deployed behind the RO–BOOM to collect any escaping oil. The same test procedure used for the OHMSETT instrumented boom would be repeated for the RO–BOOM.

Once the oil was in the Vikoma Ocean Pack boom, it would be observed for one hour (no "testing to first oil loss" would be conducted) after which the skimmer tests would commence.

The skimmer testing would involve 20 minutes skimming with the Framo ACW–400 from the side of a supply boat holding the short leg of the Vikoma Ocean Pack boom in a "J" configuration followed by 20 minutes skimming with the experimental Coast Guard Heavy Oil Skimmer. The remaining oil would then be recovered by the skimmer that performed better in its 20–minute test. A GT–185 weir–type skimmer was also to be available as a backup. The recovered oil would be pumped into two

It was not intended to determine the skimmer's performance.

FIGURE 1
PROJECT TEAM ORGANIZATION

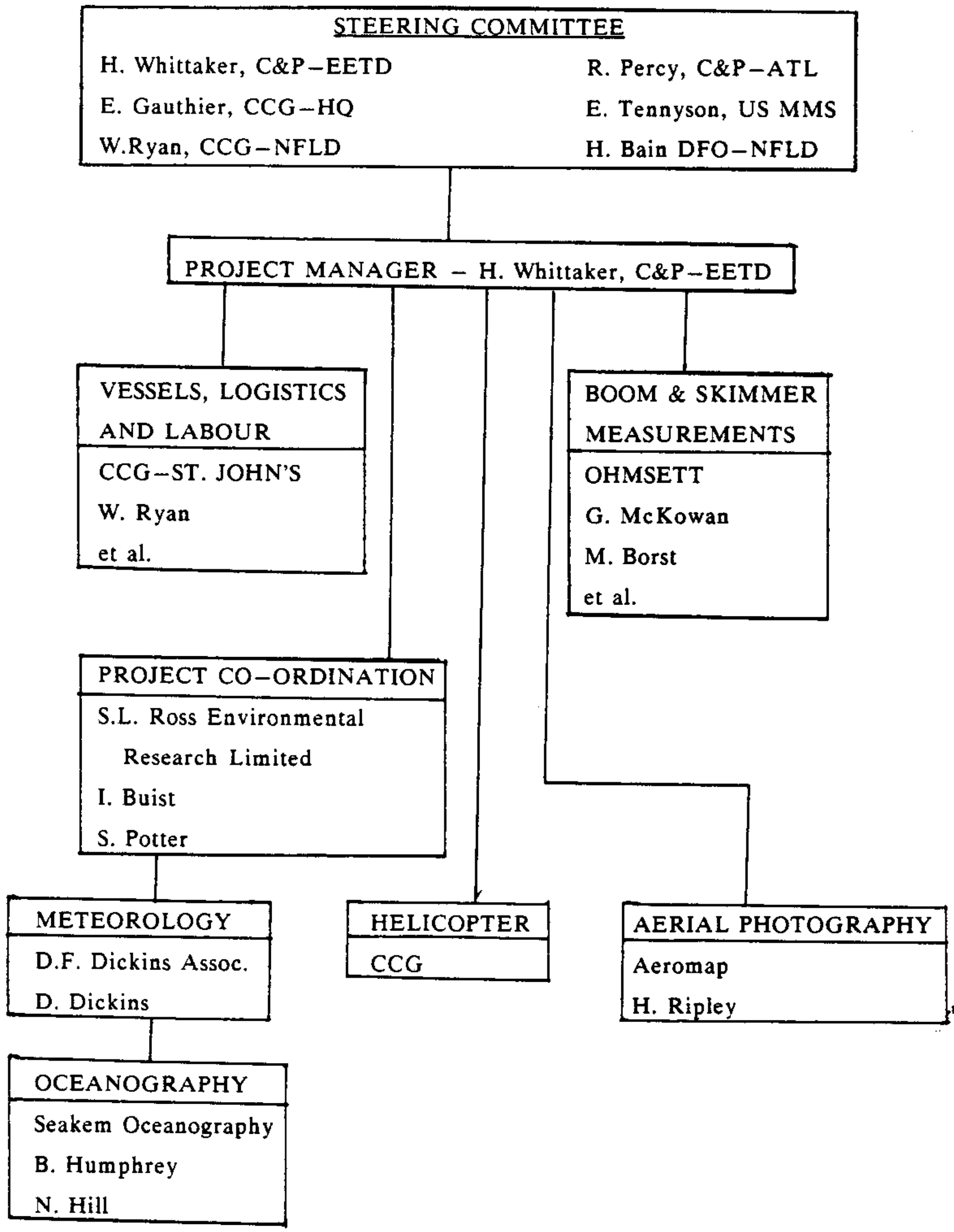
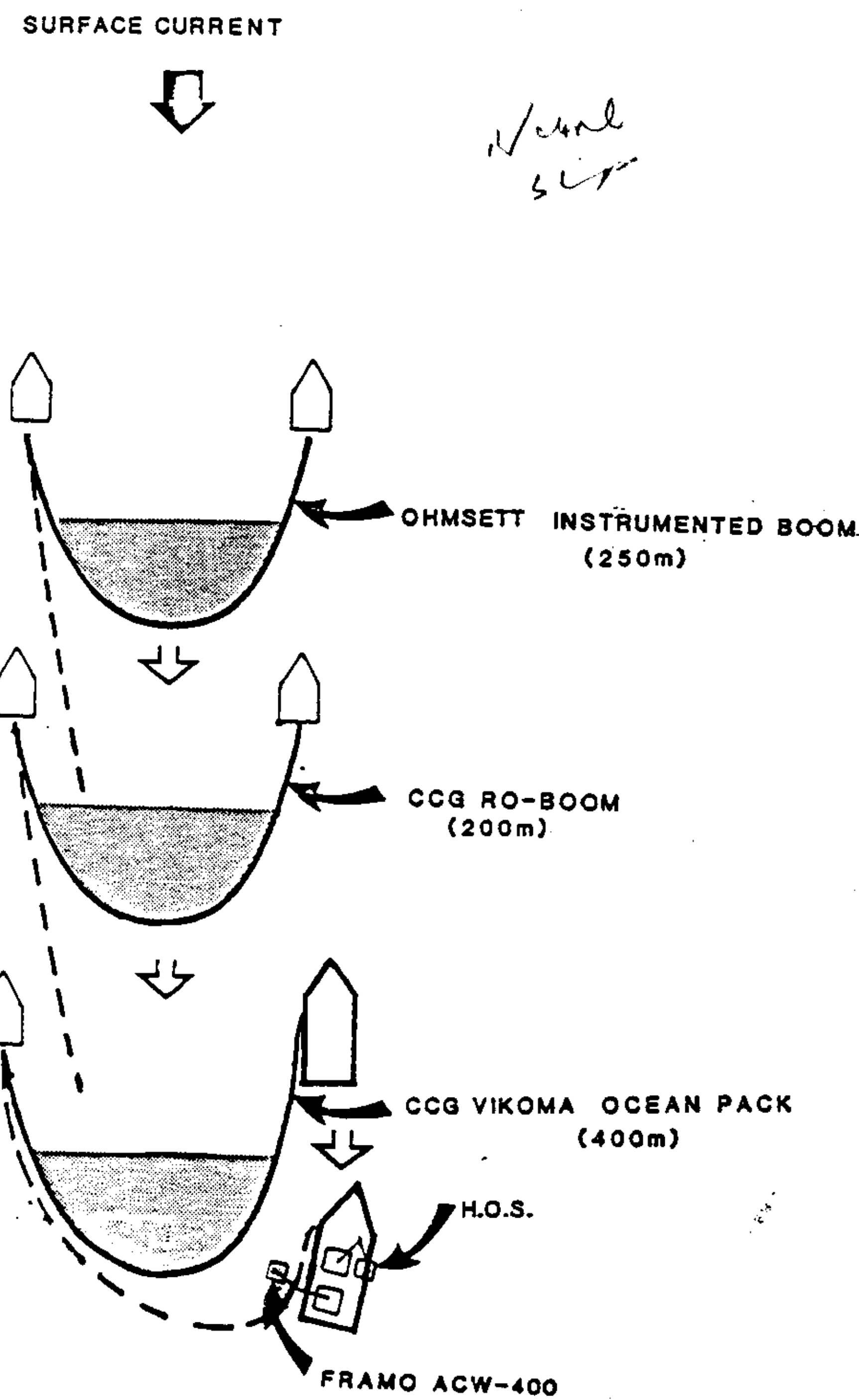


FIGURE 2 SCHEMATIC OF TEST PLAN



22 m^3 (5000 gal) deck tanks and from there back into the ship's deep tank. A steam siphon would be inserted in the hose between the skimmer and the deck tanks to break any emulsions.

A dry run was conducted just outside St. John's harbour, during which all skimmers and booms were deployed and operated, two days before the tests.

2.2 TEST SITE SELECTION

The ~~proposed~~ test area was selected in consultation with the Regional Ocean Dumping Advisory Committee (RODAC) based on the following criteria:

* any ~~minor~~ oil losses must drift out to sea (SSW currents and westerly winds)
* at least 100 m water depth
* at least 20 nm offshore
* within 2 to 3 hours sailing from St. John's

The site chosen was an area (Figure 3) centred at 47° 40'N, 52° 03'W east of St. John's. An area, rather than a specific site was selected to permit flexibility in test selection on the day of the trials and to account for "over the ground" drift during the trials. The Ocean Dumping permit may be found in Appendix 2.

The site and the possible time window for the trials (September 1 to October 31, 1987) were specifically chosen to avoid conducting the trials during the fishing season and to optimize the chances of suitable sea and weather conditions.

2.3 EQUIPMENT AND METHODS

2.3.1 The Oil

Due to the unavailability of sufficient quantities of a Grand Banks crude (about 75 m^3 was required as the volume necessary to provide realistic contained slick area and thickness) it was necessary to produce an oil with properties similar to those typical of Grand Banks' crudes (Table 1).

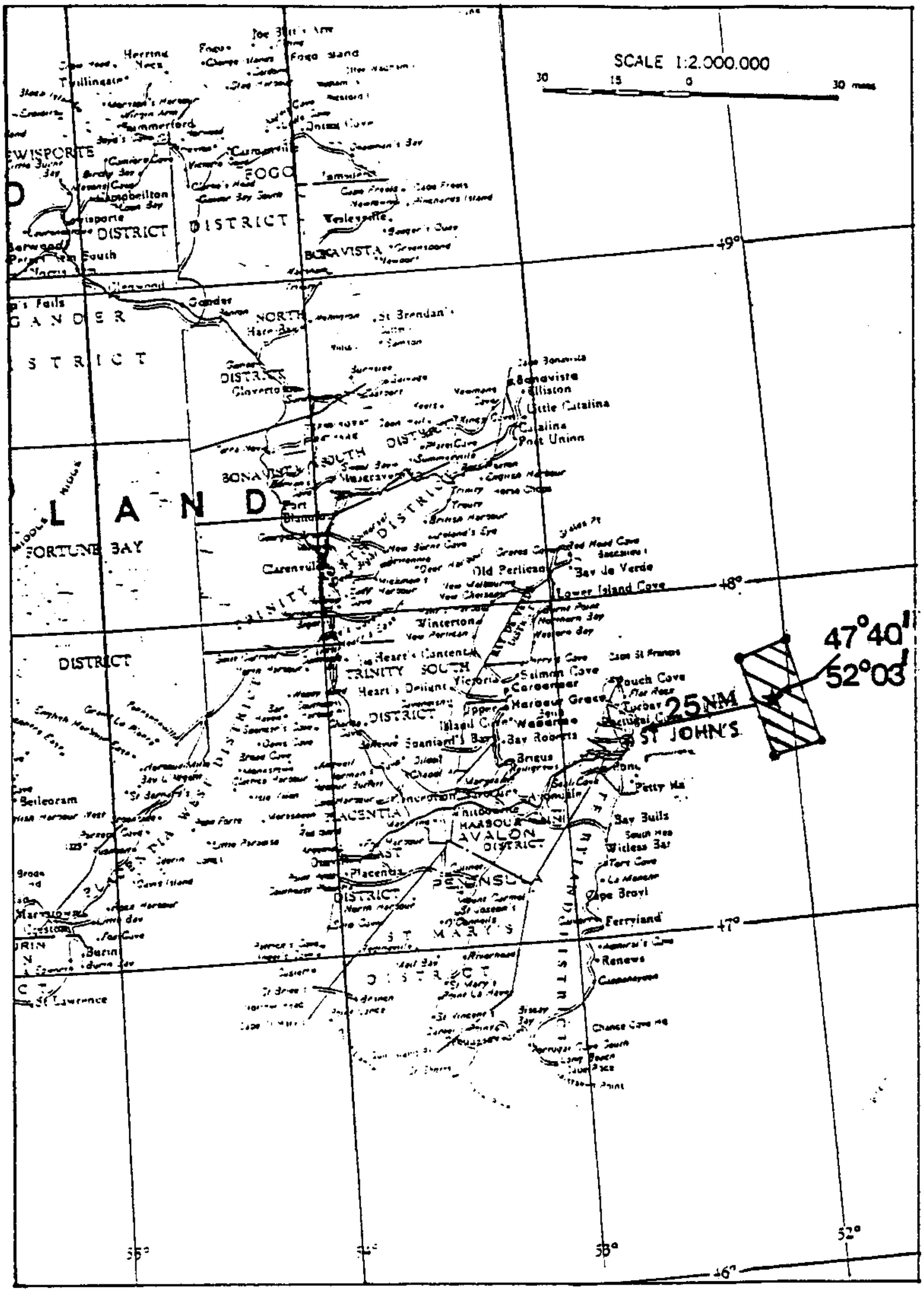


FIGURE 3 - LOCATION OF SUGGESTED TEST AREA

TABLE 1

COMPARISON OF OIL PROPERTIES

OIL	API GRAVITY	DENSITY @ 15°C (KG/M^3)	VISCOSITY (mPas)	POUR POINT (°C)
HIBERNIA	36	844	11 @ 15°C	6
AVALON	29	877	93 @ 15°C	10
TERRA NOVA				
DST–1	31	871	8.7 @ 50°C*	27
DST–2	32.9	861	16.7 @ 25°C*	12

* viscosities at ~~environmental~~ normal handling temperatures not available

In order to achieve this, Brent crude, from the North Sea, was modified by the addition of 1% by volume of slack wax (the unprocessed wax precipitate from crude oil refining operations) to raise its pour point from 0° to 6°C. Laboratory weathering studies showed that the pour point of this oil as a 10 cm thick slick in a 9 m/s wind at 15°C would increase from 6°C to 15°C in ten hours. Since there was a desire to test the OHMSETT instrumented boom (scheduled to be tested first) with a fluid oil, this degree of pour point elevation was judged to be optimum for the expected 10–12°C waters.

The fresh, doped Brent crude had a density of 839.8 kg/m^3 and a viscosity of 20 mPas at 12°C. These properties make the fresh Brent crude similar to fresh Hibernia crude oil, one of the less "waxy" of the Grand Banks oils known to date (S.L. Ross 1984).

2.3.2 Environmental Data Gathering

2.3.2.1 Meteorological Information

Wind speed and direction were recorded every 15 minutes during the trials using the anemometer and weathervane mounted on the CCGS Grenfell. These readings were subsequently corrected for the vessel's speed and heading. Water and air temperatures were also determined periodically throughout the day with mercury–in–glass thermometers.

2.3.2.2 Sea State

Although a waverider buoy was deployed at the test site, and had functioned perfectly during the dry run two days previously, no detailed wave data were collected due to receiver failure. Visual estimates of wave height, length and period and swell height, length and period were made intermittently throughout the trial.

2.3.3 Boom Performance

Boom configuration was recorded by aerial and surface video and still photography. Relative boom/surface water velocity was measured by timing the drift of wood chips over a known distance along the side of the boom tow vessels. This data was converted to a relative velocity at the boom pocket by:

$$V = \frac{(U_1 + U_2)}{2} \cos (\theta/2)$$

where V = relative boom/water velocity (m/s)

U_1, U_2 = measured drift at tow vessels 1 and 2 (m/s)

θ = angular separation of the two vessels (°)

= difference in vessel headings at time of drift measurement

The rate of oil leakage from the booms was estimated from aerial video and still photography by determining the width of sheen leaking past the boom and multiplying by the relative boom/water velocity and an assumed slick thickness (10 um for sheen, 1 mm for dark oil). This technique provides a reasonable relative comparison of boom leakage rates for booms tested under similar conditions.

General boom performance (wave conformance, ease of deployment, and recovery, durability, manoeuvrability etc.) were monitored throughout the trial and recorded by surface video and still photography.

2.3.4 Skimmer Performance

The deployment, operation and retrieval of the three skimmers (the Framo ACW–400, the H.O.S. and the backup GT–185) was recorded on videotape and still photographs. Observations on general skimmer performance (sea keeping, proximity to thick oil, flow of oil to skimmers, etc.) were made visually by trained personnel.

The recovery performance of each skimmer was measured by OHMSETT staff using the following equipment (see Appendix 3 for the calibration curves):

* a 10 cm (4 inch) Venturi meter with Rosemount pressure gauges and a Telog data recorder was used to monitor fluid flowrates from each skimmer during recovery operations. The output used from the data recorder was a 3 second average flowrate. Twenty consecutive outputs were later averaged to give a one minute average flow. This was necessary to remove the effects of the vessel's roll on the pressures recorded;
* periodic soundings of the 23 m^3 (5000 gallon) receiving tanks were made to measure recovered fluid volumes;
* small samples of recovered fluid were drawn from the skimmer discharge every five minutes during recovery operations and analyzed for density (by weighing a known volume), viscosity (Brookfield viscometer) and water content (by centrifugation followed by volumetric analysis);

* stratified samples (covering 15 cm = 6 inches of fluid each) of the recovered fluid in the two tanks were taken with a Johnson sampler and analysed for oil, free water and emulsified water content to determine overall oil recovery factors.

2.3.5 Oil Weathering and Fate

Emulsified oil samples dipped from the recovery tanks were analysed in Ottawa (density and viscosity) and chromatographically compared to artificially weathered oil to determine oil weathering rates and behaviour.

A computer prediction model (S.L. Ross and DMER 1987) was used to ~~hindcast~~ forecast the ~~calculated~~ fate of the oil slick remaining after the completion of the trials. The oil properties used as input were for a Hibernia crude modified to correspond closely to the Brent Crude used in the trials. The model was run with a range of wind speeds to cover the recorded post–trial conditions.

Spill areas were determined by analyzing the aerial photographs and videotape taken during the trials; an overflight was conducted the following day during which the position of the remaining slick, its size and general appearance were noted. A surface vessel also steamed to the reported position of the slick on the day after the trials to collect a sample.

3.0 RESULTS AND DISCUSSION

3.1 DRY RUN

On September 21, 1987 a dry run of all equipment (booms, skimmers and measurement equipment and techniques) was conducted outside St. John's Harbour. Winds were calm during the dry run and only a slight (0.5 m), long period swell was running at the dry run site.

The OHMSETT instrumented boom was deployed first. This went smoothly, but the boom proved difficult to tow and position while in a catenary without twists developing in the boom. During manoeuvres with the boom an electrical cable connecting the sensors to the onboard data acquisition system was accidentally severed requiring repairs.

The deployment and retrieval of the RO–BOOM over the gunwale of the CCGS Sir Humprey Gilbert proved tedious and time consuming and its positioning with CCG 214 and a Boston Whaler proved slow. Thus a decision was made to obtain the services of the offshore supply vessel M/V Triumph Sea for deployment and manoeuvring of the RO–BOOM during the tests. A second vessel (M/V Beinir) was also obtained to hold the other end of the RO–BOOM thus freeing CCG 214 to replace CCG 206 as one of the OHMSETT instrumented boom tow boats and removing the requirement to use a Boston Whaler to hold one end of the RO–BOOM.

[redacted]

In the test protocol (Appendix 1) it was intended to have the oil discharged from the CCG Dumb Barge which was to be towed to the scene by the charter OSV (MV Terra Nova Sea). This proved unnecessary because the latter was classified as an oil recovery vessel and permitted to carry oil in her deep tanks.

considerably simplified the oil discharge and recovery operations.

The Vikoma boom was successfully deployed from the CCGS Grenfell and manoeuvred in a "U" and a "J" configuration in conjunction with the M/V Terra Nova Sea during the dry run. The Framo ACW–400 and the H.O.S. were also successfully deployed, operated with water and recovered. The wave rider, meteorological instruments and skimmer recovery measurement systems all operated ~~perfectly~~ normally during the dry run.

Following the dry run the wave rider was repositioned at the test site, the damaged electrical cable on the OHMSETT instrumented boom was repaired and the appropriate equipment was transferred to the newly selected vessels. A helicopter overflight of the test site was conducted the day before the tests to check the area for seabirds.

3.2 GENERAL DISCUSSION OF TEST DAY EVENTS

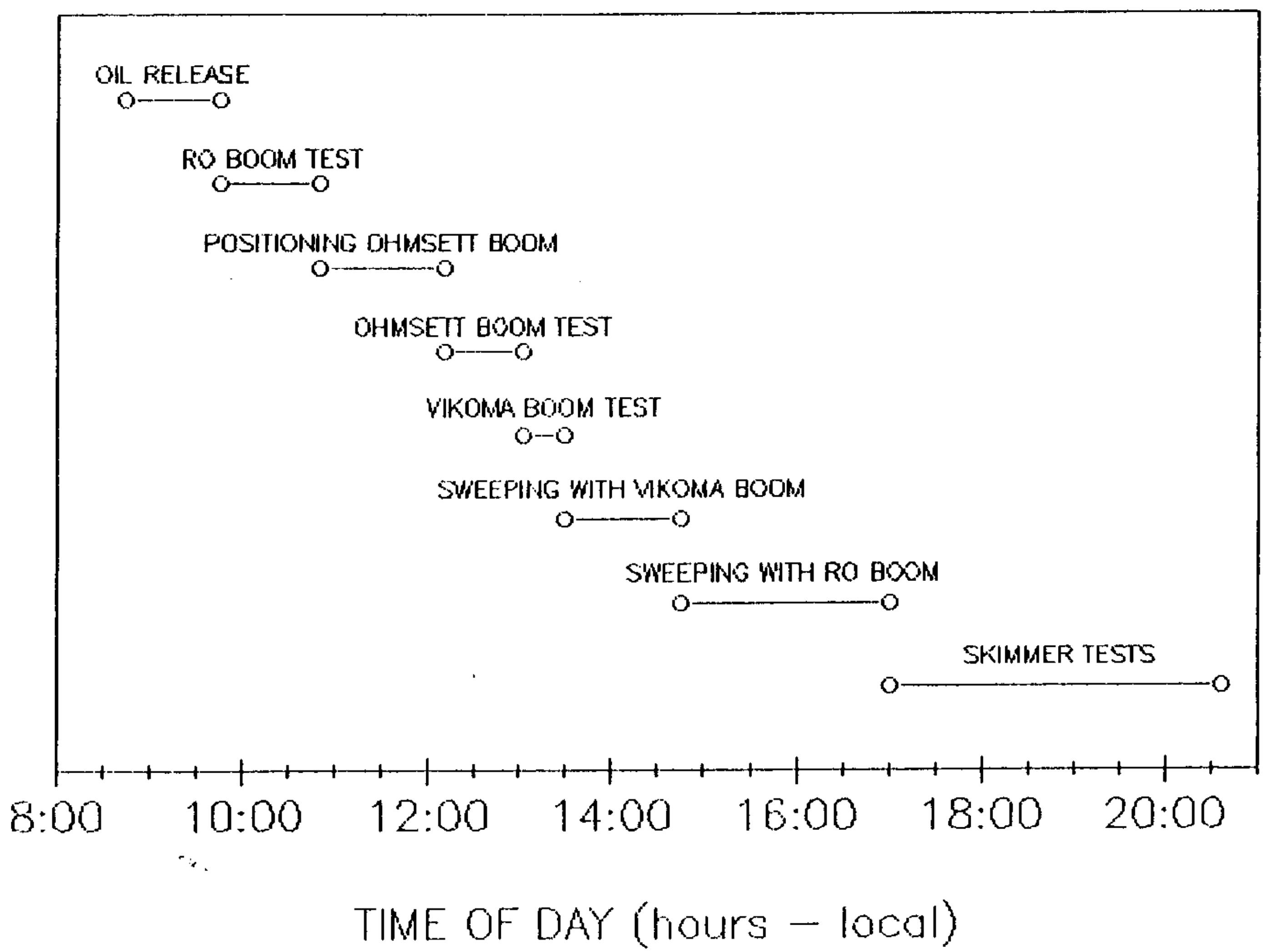
Figure 4 shows the sequence of activities on 24 September 1987, the day of the trials. Due to the need for sea state 3–4 (15–18 knot winds; 0.8–1.2 m waves) related to the OHMSETT instrumented boom data collection and in view of the forecast wind (10 knots, increasing to 15 by mid–day) and wave (0.5 m, increasing to 1 m by mid–day) conditions it was ~~necessary~~ decided to ~~further~~ alter the test protocol and release the oil into the RO–BOOM first, test the RO–BOOM and then release the oil into the OHMSETT instrumented boom. This change was felt to be crucial to the success of the instrumented boom tests. ~~in order that they meet their objective~~.

The oil was pumped from the stern of the M/V Terra Nova Sea, commencing at 0846 and finishing at 0944, into the mouth of the RO–BOOM being held by the M/V Triumph Sea and the M/V Beinir (Figure 5). Some 67.7 m^3 (17,885 gal) of oil were released in this manner at approximate position 47° 42'N, 52° 47'W. All the oil entered the mouth of the boom catenary.

From 0944 to 1050 the seakeeping and oil containment capabilities of the RO–BOOM were evaluated at relative boom/water velocities of less than 0.4 m/s (0.75 knots) (Figure 6). The oil was released from the RO–BOOM by letting go the tow line from the M/V Beinir at 1050; no testing to first loss (i.e., towing at speeds in excess of 0.5 m/s = 1 knot) was conducted with the RO–BOOM.

FIGURE 4

TRIAL TIMETABLE



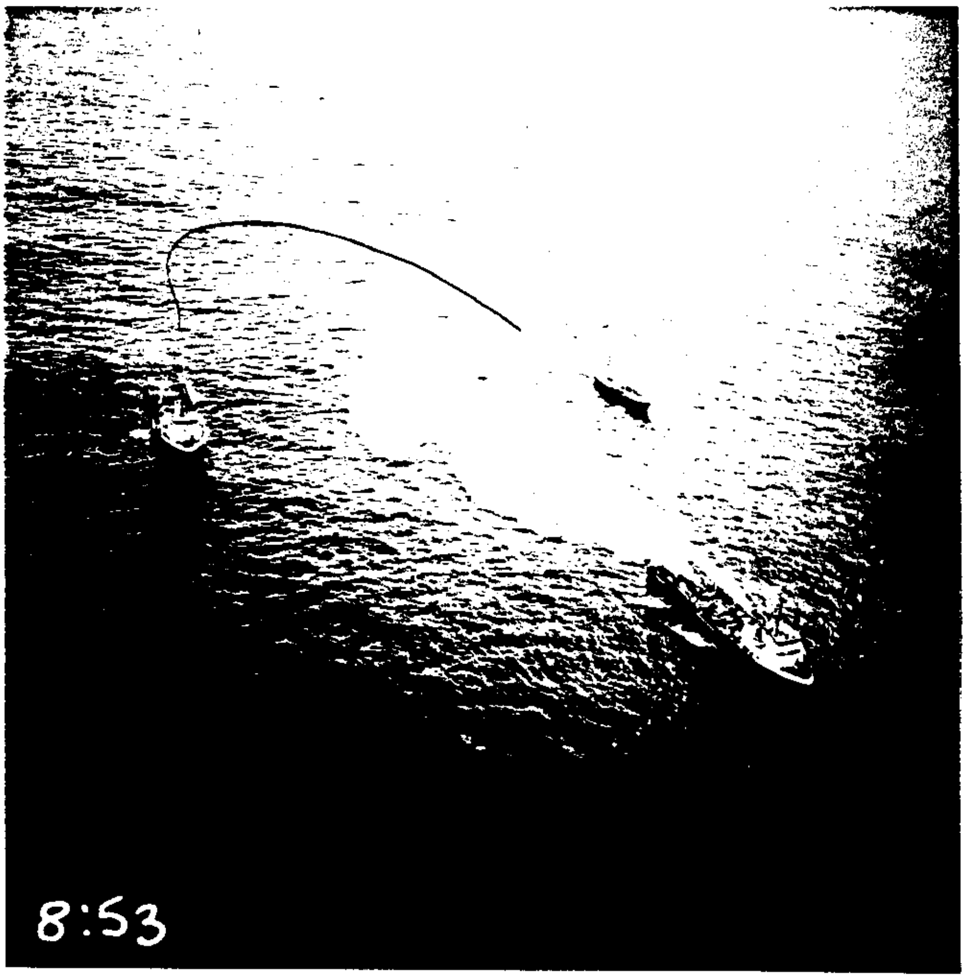


Figure 5 – Oil drifting into RO–BOOM

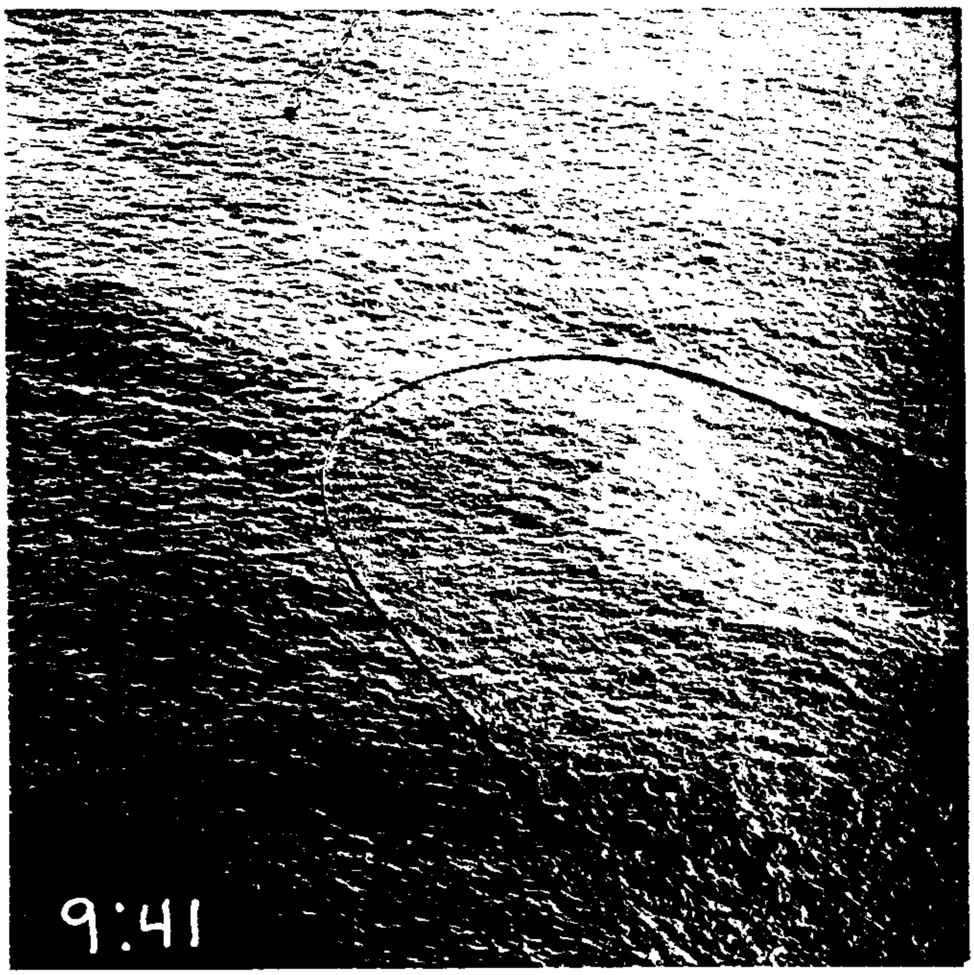


Figure 6 – Testing of RO–BOOM; note thick oil in pocket. Losses are sheen only.

Difficulties were encountered in holding the OHMSETT instrumented boom in position without the boom twisting (Figure 7). As ~~such,~~ a result at the time of the oil release from the RO–BOOM, the OHMSETT instrumented boom was approximately 1.5 km downdrift of the thick oil. After about an hour of manoeuvring, ~~a portion~~ of the thick slick was captured by the OHMSETT instrumented boom. During this time the Vikoma boom was deployed in a catenary in the path of the drifting thick oil (Figure 8). Testing of the OHMSETT instrumented boom commenced at 1210 and concluded at 1302.

Although the Vikoma boom was positioned across the drift path of the slick, in manoeuvring to intercept the oil released from the OHMSETT instrumented boom at the completion of its test, some of the thick oil not originally contained by the OHMSETT boom drifted past the mouth of the Vikoma boom (Figure 9). This manoeuvring also caused the loss of the small volume of oil already collected. After one half hours testing of the Vikoma boom containing thick oil, the M/V Grenfell (on the starboard) began to slowly move ahead to form a "J" boom configuration for the skimming tests. Unfortunately, because the vessels were heading into a 7–10 m/s (15–19 knot) wind, the Grenfell moving forward caused the relative boom/water velocity to exceed 0.5 m/s (1 knot) and all the oil collected escaped by 1348 (Figure 10). Following this the Vikoma boom was repositioned with the vessels heading downwind and some thick oil was recaptured by the Vikoma boom. Much of this oil was lost under the boom a second time when manoeuvring to form a "J" boom configuration for the skimming tests due to excessive speed. Attempts were made to deploy the Heavy Oil Skimmer at 1445 into what remained of the oil in the Vikoma boom ~~however~~ but the boom pocket had collapsed and it proved impossible to insert the skimmer into the oil (Figure 11).

Between 1500 and 1700 the RO–BOOM was used in a "U" configuration oriented downwind to chase down and capture the thick oil slicks. From 1700 to 2036 the skimmer tests were conducted from the skimmer vessel (M/V Terra Nova Sea) stationed broadside to the RO–BOOM pocket (Figure 12).

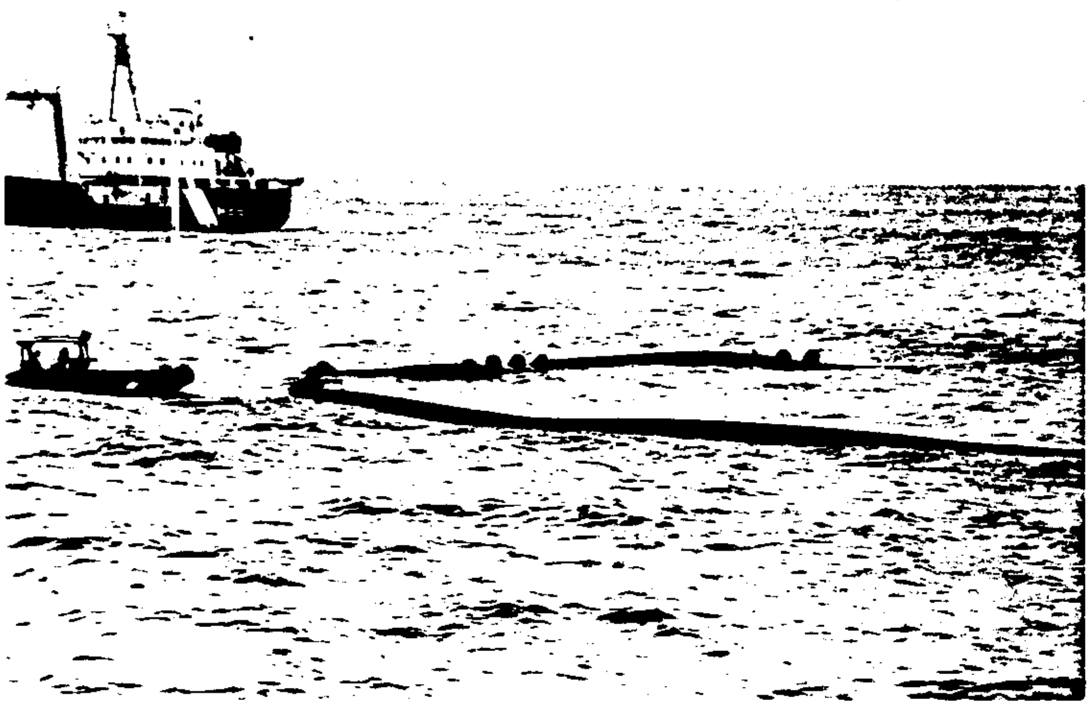


Figure 7 – OHMSETT instrumented boom twisting during manoeuvring

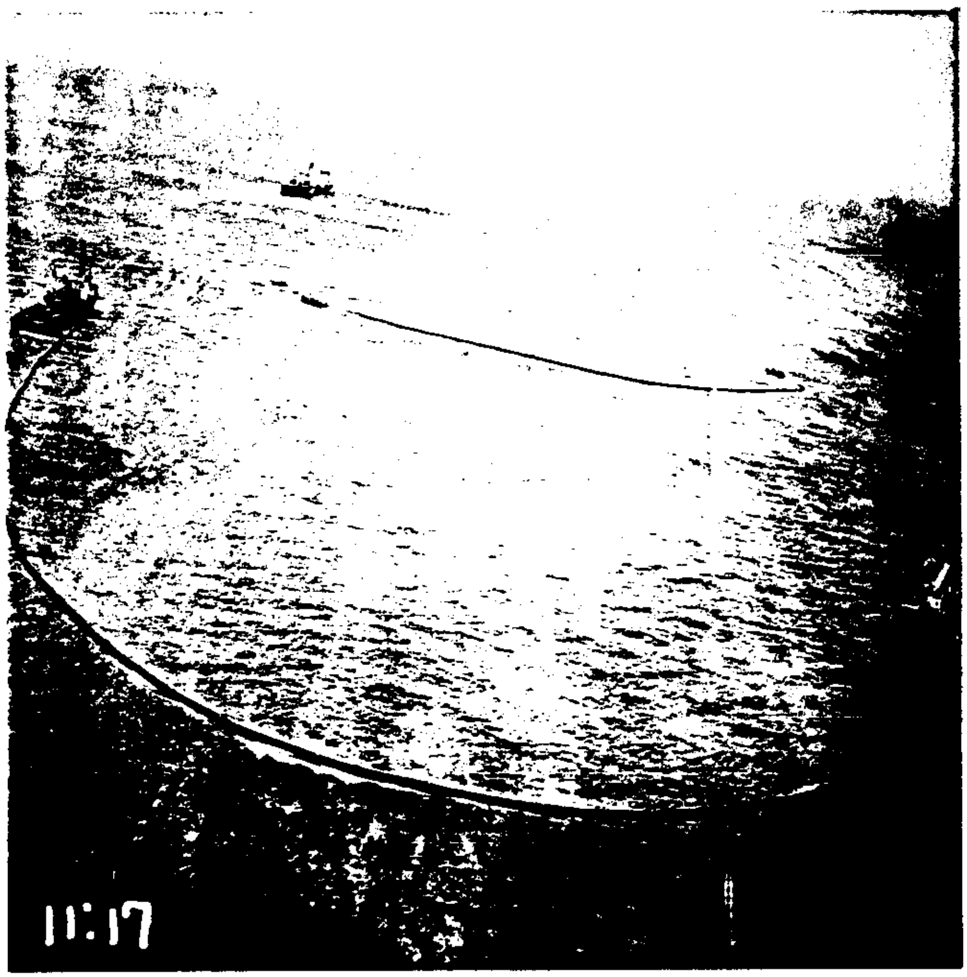


Figure 8 —Vikoma Ocean Pack deployed behind OHMSETT instrumented boom in path of slick

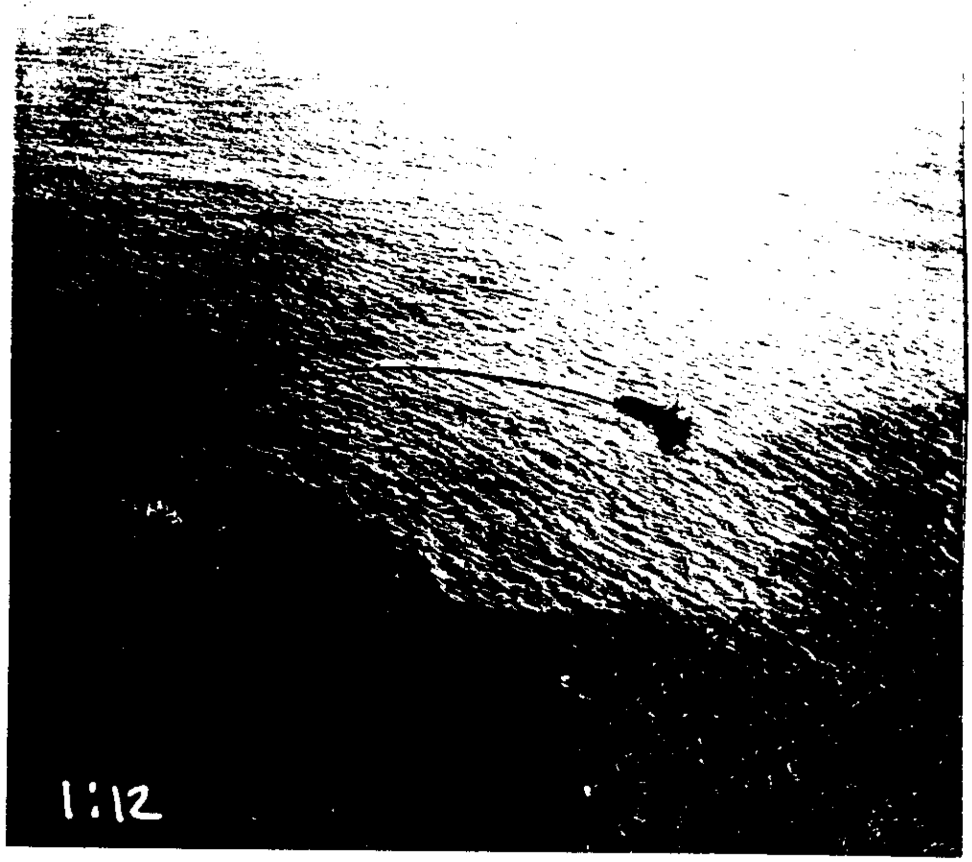


Figure 9 – Vikoma Ocean Pack being manoeuvred to intercept oil from OHMSETT instrumented boom.

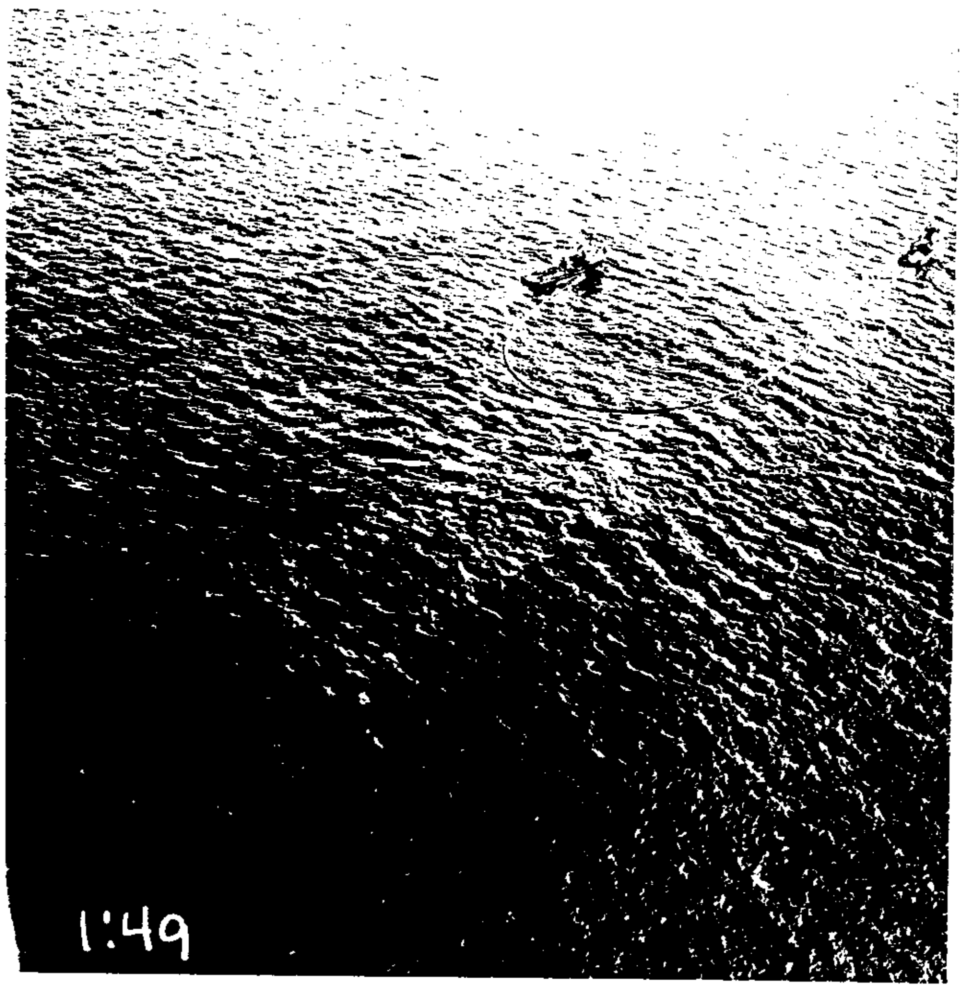


Figure 10 – Oil lost from Vikoma Ocean Pack during manoeuvring boom into "J"

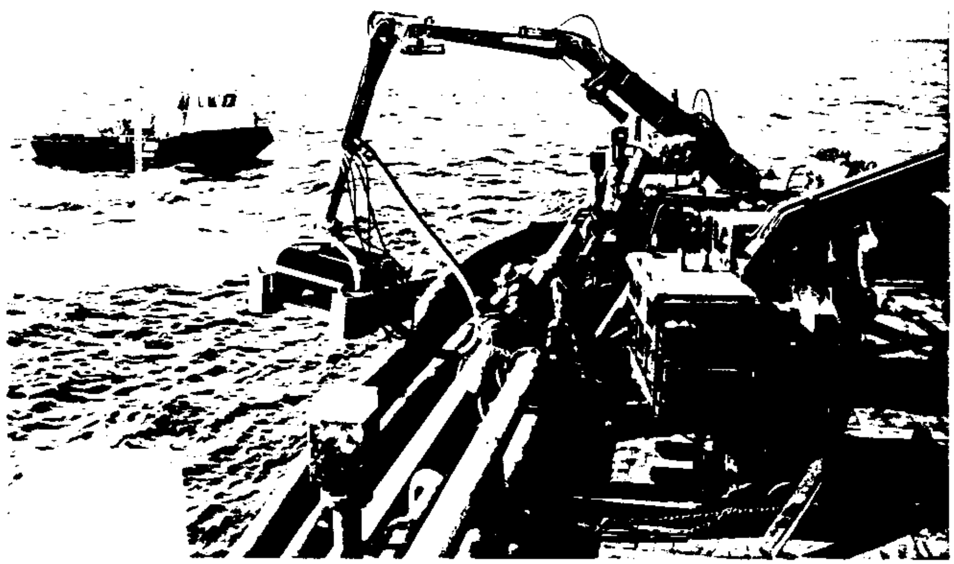


Figure 11 – Attempted deployment of Heavy Oil Skimmer into Vikoma Ocean Pack boom pocket

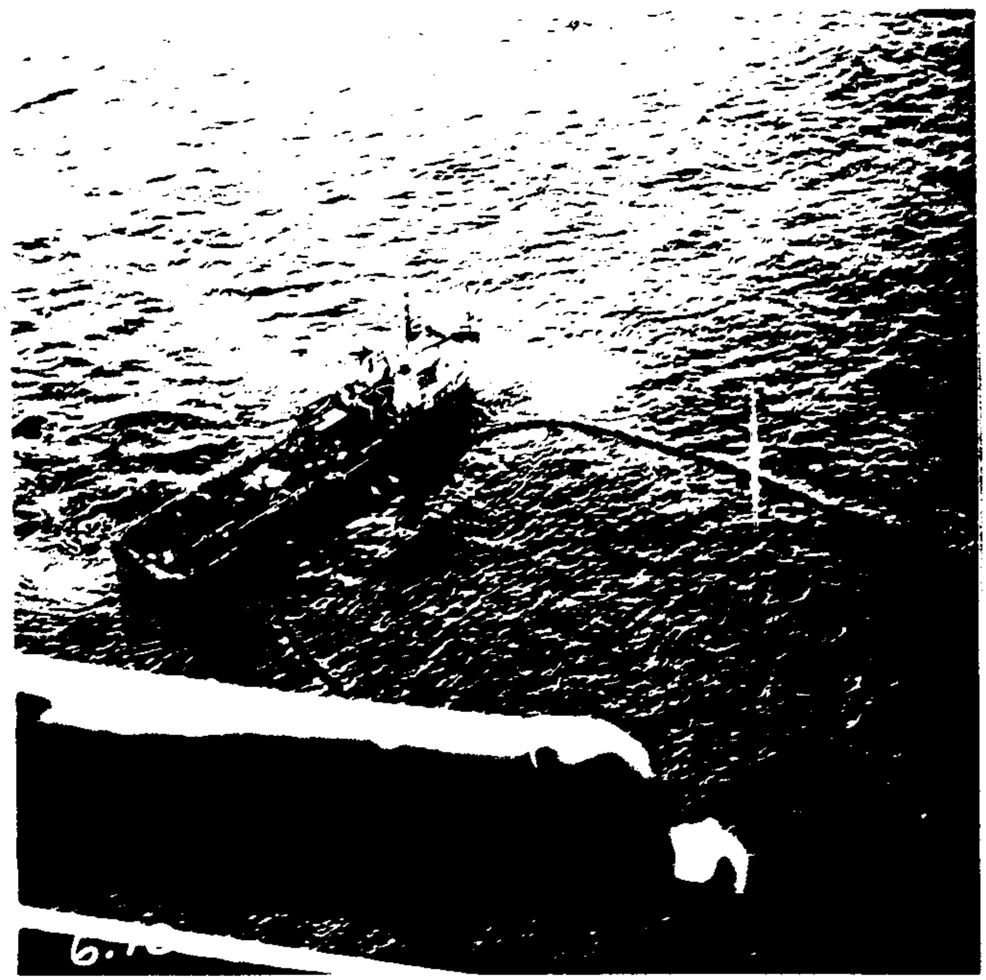


Figure 12 – Skimmer tests being conducted in pocket of RO–BOOM

The skimmers were tested in the following sequence:

1) The Heavy Oil Skimmer was deployed; no recovery was observed.
2) The Framo ACW–400 skimmer was deployed and operated for 23 minutes. At this point the major objectives of the skimmer tests ~~have~~ had been met and the decision was made to recover the oil by the best means possible. Fortunately a quantity of Elastol was available onboard the M/V Terra Nova Sea and this was applied to the oil to enhance its recovery. In addition, the backup GT–185 skimmer was deployed to attempt recovery of the viscous emulsion.
3) The Heavy Oil Skimmer was deployed; problems with the pump precluded recovery operations and one drum was damaged.
4) The GT–185 skimmer was deployed and operated for 29 minutes.
5) The Heavy Oil Skimmer was redeployed with only one drum fully operational. During this last attempt the discharge hose burst just as the initial measurements of recovery were being made.

The trials ended at 2036 due to the failure of the Heavy Oil Skimmer discharge hose, darkness and increasing winds forecast for the area.

3.3 ENVIRONMENTAL CONDITIONS

Complete listings of the raw data may be found in Appendix 4.

3.3.1 Winds

Figures 13 and 14 show the wind speed and direction, respectively, recorded at the test site. The wind speed remained relatively constant in the morning at 5 to 6 m/s (10 to 12 knots) and increased in the afternoon to 7 to 9 m/s (14 to 18 knots). Winds in the evening increased further to 9 to 10 m/s (18 to 20 knots). The wind direction remained relative constant from the southwest. Over the following 48 hours the winds shifted from southwesterly to westerly and averaged 4 to 8 m/s (8 to 16 knots), increasing to 8 to 13 m/s (16 to 25 knots) with gusts to 18 m/s (35 knots), 48 hours after the completion of the trials.

FIGURE 13

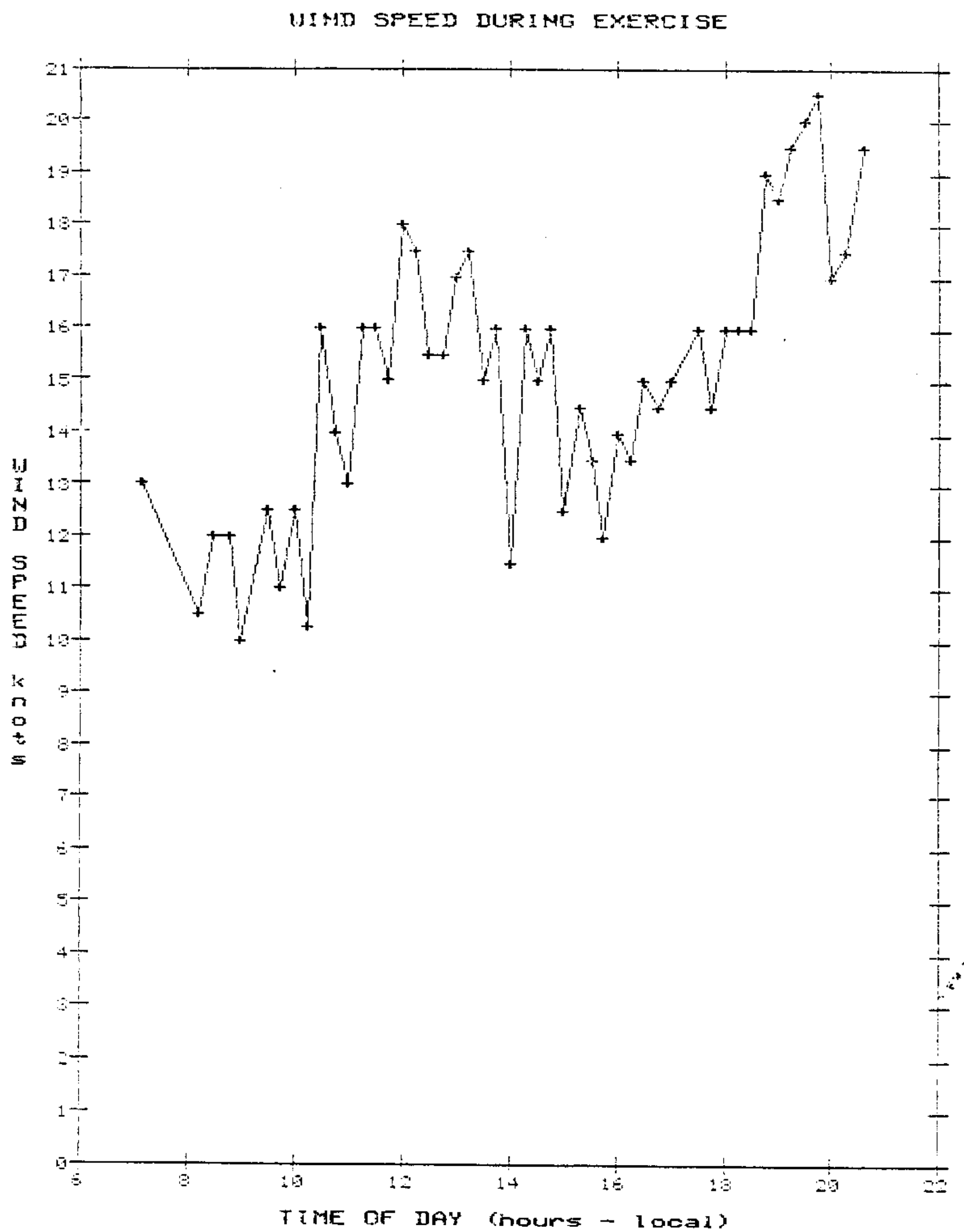
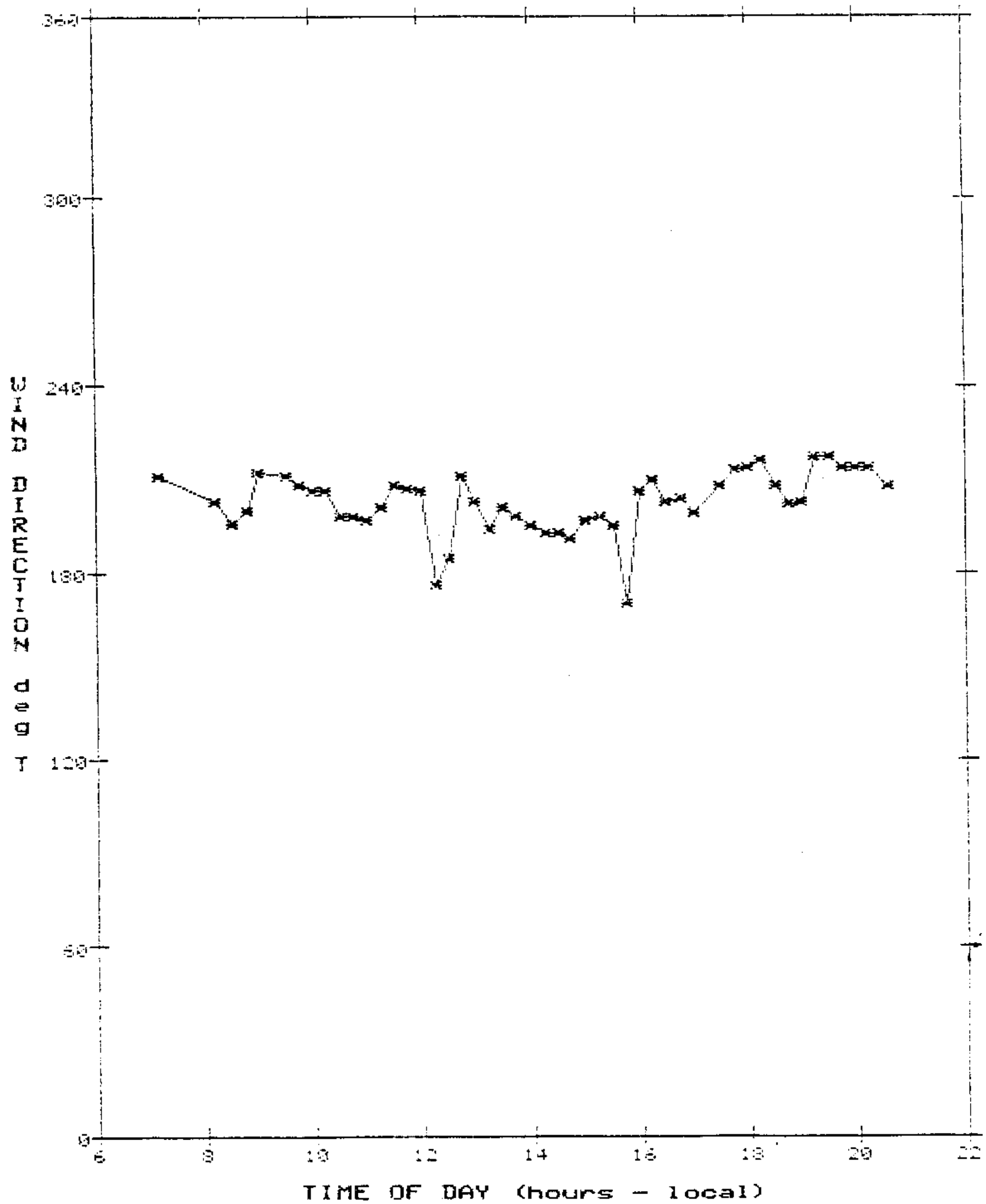

WIND SPEED DURING EXERCISE
WIND SPEED knots
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
6
8
10
12
14
16
18
20
22
TIME OF DAY (hours - local)

FIGURE 14

WIND DIRECTION DURING EXERCISE



3.3.2 Sea State

Figure 15 shows the visually estimated wind wave and swell height during the trials. At the commencement of the trials the waves averaged 0.5 m (Sea State 2) with a swell of 2.5 m (personnel in small boats reported occasional swells of 4 m). As the day progressed the wave height increased to about 1.3 m (Sea State 3–4) and the swell height decreased to 1.5 to 2.0 m.

3.3.3 Temperature

Figure 16 gives the air and water temperatures recorded during the trials. The water temperature remained constant at 12°C throughout the day. Air temperatures increased from 12°C at sunrise to 14°C by sunset.

3.4 BOOM PERFORMANCE

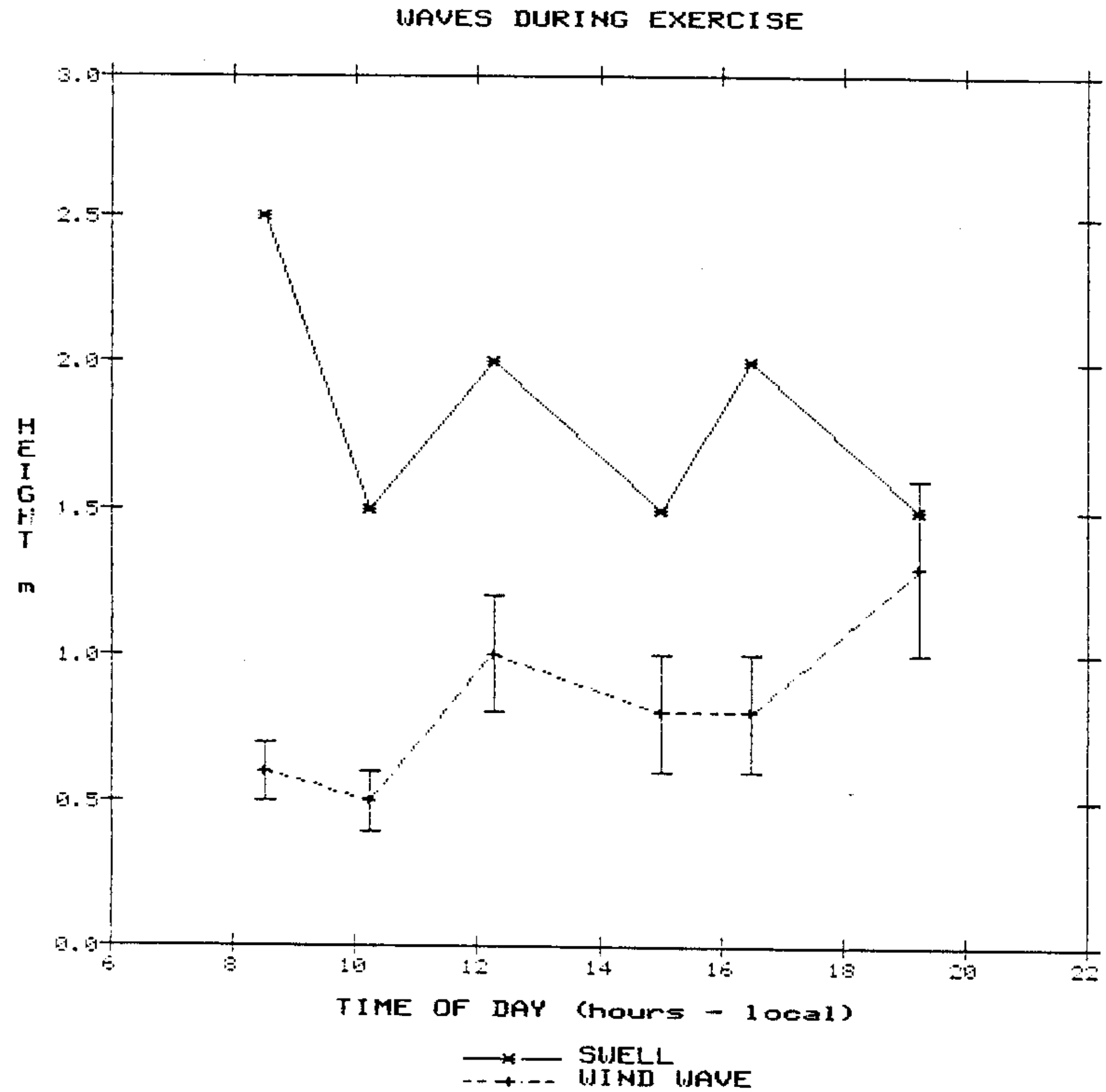
This section of the report deals only with the evaluation of the RO–BOOM and Vikoma Ocean Pack. Details of the testing of the OHMSETT instrumented boom are covered in a separate report (McKowan and Borst 1987).

3.4.1 Deployment and Recovery

3.4.1.1 RO–BOOM

The deployment of the two 200 m sections of the RO–BOOM required approximately 110 minutes over the gunwale of the CCGS Sir Humphrey Gilbert during the dry run and 105 minutes over the stern of the M/V Triumph Sea during the trials. Deployment over the stern of a supply boat was much easier than over a gunwale.

FIGURE 15



WAVES DURING EXERCISE
3.0
2.5
2.0
1.5
1.0
0.5
0.0
HEIGHT m
6
8
10
12
14
16
18
20
22
TIME OF DAY (hours - local)
SWELL
WIND WAVE

Recovery of the RO–BOOM over the gunwale took 80 minutes and was very difficult even in the calm conditions prevalent during the dry run. Up to 14 personnel were involved in boom recovery in this instance. Recovery over the stern of a supply boat was much less labour intensive (six personnel) and easier even though it was dark and the winds and seas were much higher than during the dry run. The time required to recover the boom was 100 minutes, slightly longer than during the dry run because the boom was rinsed of oil as it was being recovered.

3.4.1.2 Vikoma Ocean Pack

The deployment of the Vikoma boom was accomplished in approximately 20 minutes during both the dry run and the trial. Recovery onto the hydraulic reel took about 30 minutes each time, however, it was necessary to remove the boom from the reel after each recovery and restow it into the boom box. This required about an hour. Deployment required three personnel; recovery required six, and restowing the boom required eight personnel.

3.4.1.3 Comparison

The deployment and recovery of the Vikoma boom is faster and less labour intensive than that of the RO–BOOM, however, in the context of offshore spill response both booms were judged to be acceptable, providing these operations are conducted from the aft deck of a supply vessel. It should be noted that Roulunds, the manufacturers of the RO–BOOM, are continuing to improve the valving system and hope to reduce deployment times to about 10 minutes per 200 m section.

3.4.2 Manoeuvring and Durability

Both booms proved to be very manoeuvrable and no problems with overturning or twists were noted. No damage to the RO–BOOM was noted after 17 3/4 hrs deployment including 3 hrs skimming operations; all the floatation chambers were still fully inflated when the boom was recovered.

The Vikoma boom suffered one incident of sinking when excessive strain during manoeuvring caused the band holding the air chamber to the power unit to slip off. This problem was rectified in about one half hour and the boom itself was undamaged.

Overall, the RO–BOOM was judged to be somewhat more durable for long–term offshore deployment because it does not depend on the continuous operation of a power source and the tearing and loss of one or more floatation units should not affect the overall integrity of the boom. Power failures and large tears can cause temporary losses of containment capability for the Vikoma Ocean Pack. Both booms were judged sufficiently manoeuvrable and durable for use offshore.

3.4.3 Sea Keeping and Oil Retention

3.4.3.1 RO–BOOM

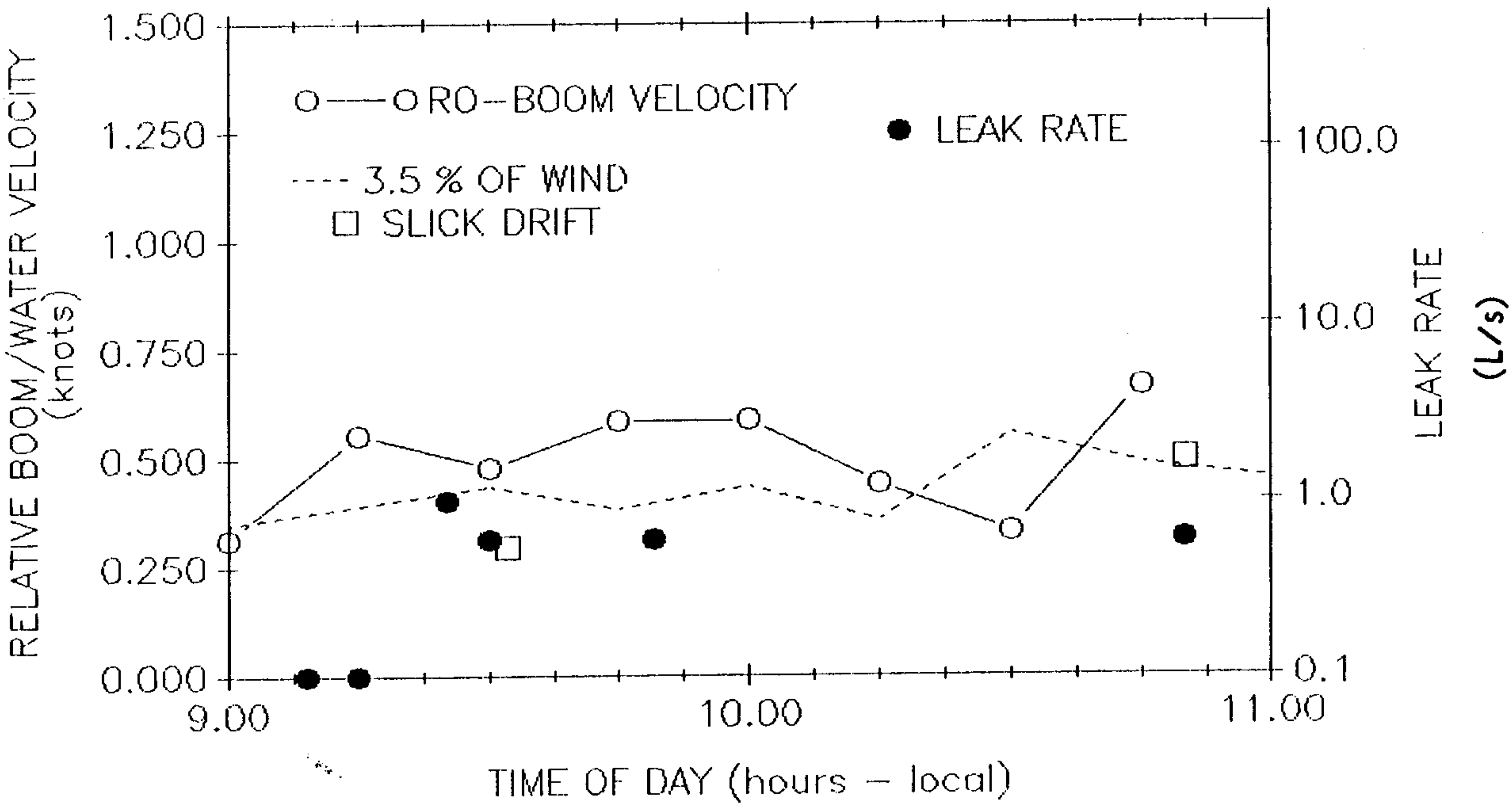
Oil was in contact with the RO–BOOM for two time periods during which data on seakeeping and oil retention was collected: first during the oil release and RO–BOOM trials from approximately 0900 to 1050 and second during the skimmer trials from 1700 to 1900 hrs. At all times the RO–BOOM followed the waves and swell very well and maintained its desired configuration.

Figure 17 compares the visually estimated oil leakage rate from the RO–BOOM during its morning trials with the calculated relative boom/water velocity. Also shown are the calculated wind–induced surface water velocity and measured (from aerial videotapes) slick drift rate. The three measures of relative water velocity agree reasonably well; the calculated relative boom/water velocity is generally slightly higher than the other two due to the need for the one tow vessel (M/V Beinir), to maintain steerage way.

The estimated oil leakage rates are very low initially at approximately 0.1 L/s because only small amounts of oil had reached the boom pocket (Figure 18). By 0930 when most of the oil had reached the boom pocket the leak rate had increased to 0.5 to 1.0 L/s (Figure 19); this leak rate remained reasonably constant throughout the test

FIGURE 17

RO–BOOM LEAKAGE



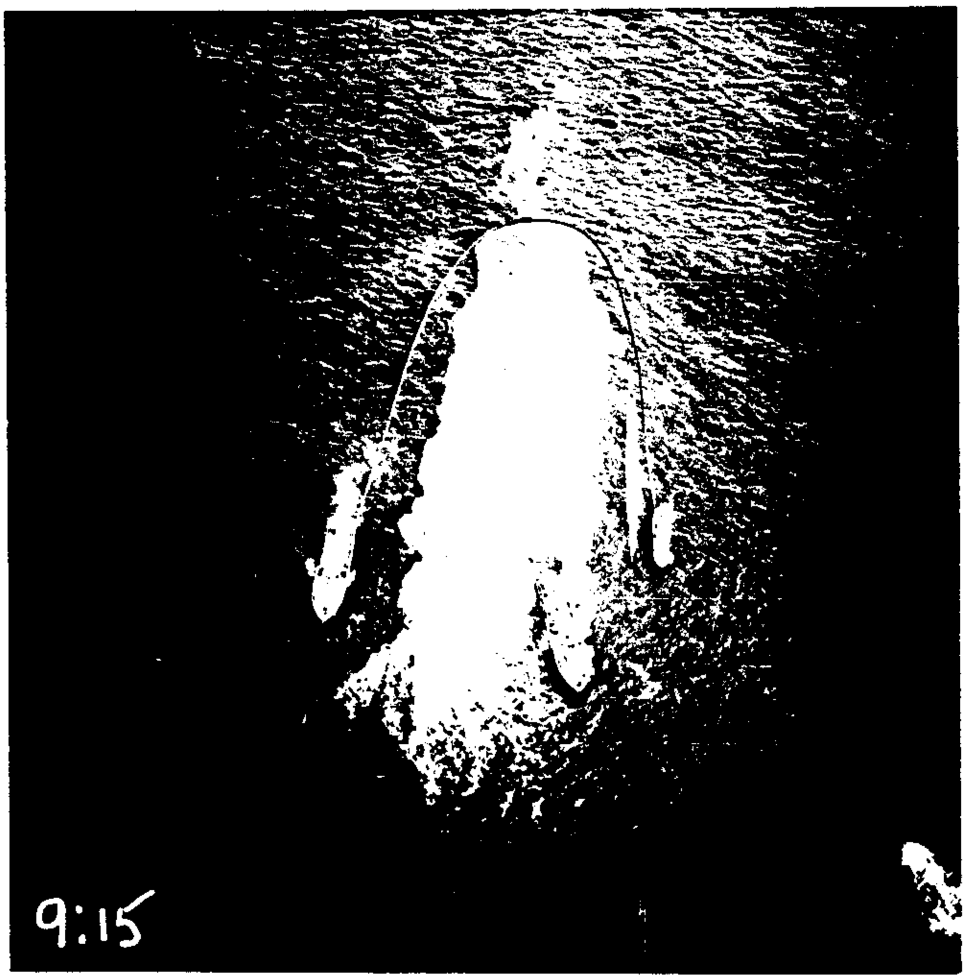


Figure 18 —Leakage of sheen past RO–BOOM; note very little oil against boom

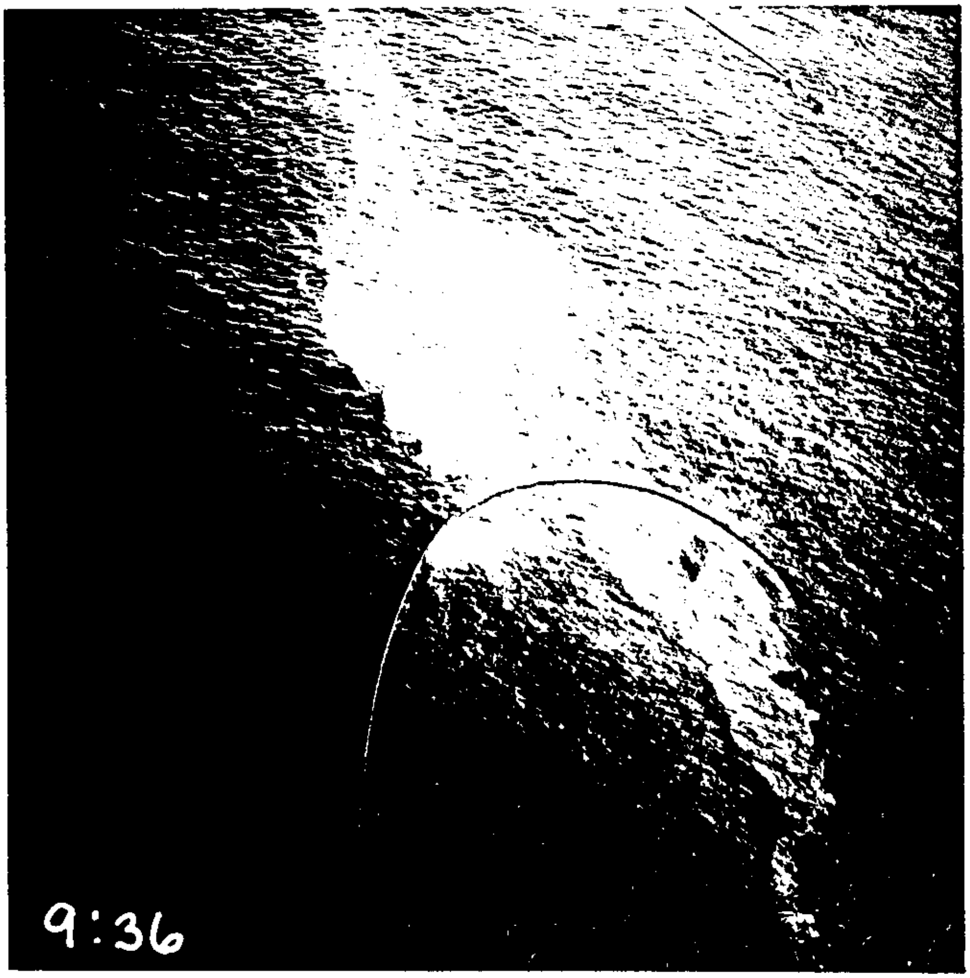
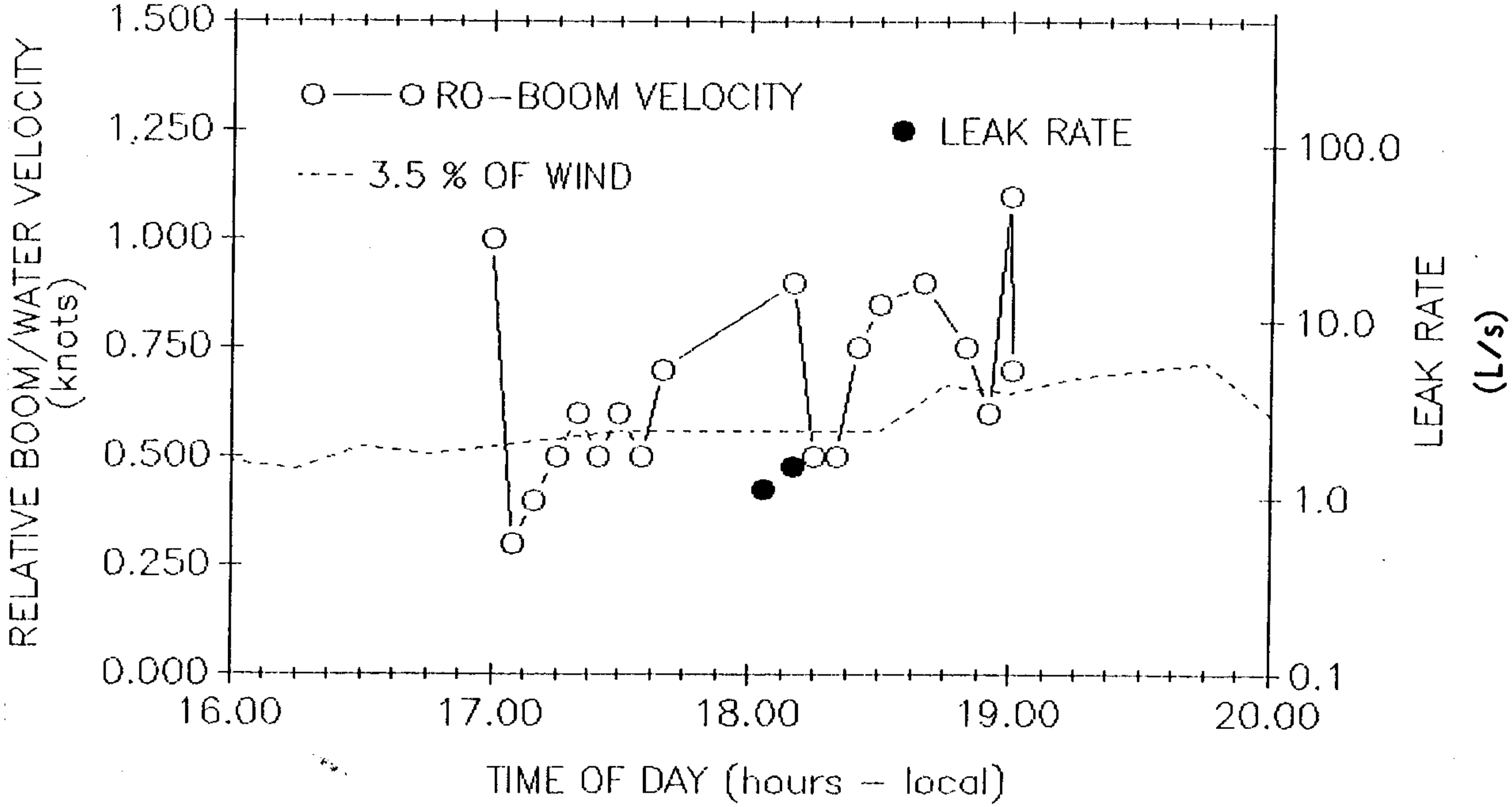


Figure 19 —Greater leakage of sheen past RO—BOOM: note change in width of sheen due to increase in volume of oil contained compared to Figure 18

FIGURE 20

RO-BOOM LEAKAGE DURING SKIMMER TESTS



period (Figure 17). Some splashover of oil at the joints between flotation sections was observed near the end of the test (around 1050) when the winds had increased to 7 m/s (15 knots) and the relative boom/water velocity was calculated to be around 0.3 m/s (0.6 knots). The volumes of oil lost were small.

One thickness measurement in the boom pocket near the end of the test period was reported; ~~it indicated~~ The contained slick ~~to be an~~ was estimated 30 cm thick at the boom. Simultaneous aerial video and still photography shows an area of contained oil of some 200 m^2. Assuming the slick thickness was relatively constant throughout (Wicks 1969; Lau and Kirchhefer 1974; Delvigne 1984), this would translate to a contained volume of approximately 60 m^3 or almost all the 67.7 m^3 discharged. The low observed leakage rates would tend to substantiate the conclusion that virtually all the oil released into the RO–BOOM was contained for the duration of its test. As noted previously no testing to first loss, by increasing speed, was conducted with the RO–BOOM though splashover losses were noted by personnel in a small boat near the end of the test.

Figure 20 shows a comparison of relative RO–BOOM/water velocity and oil leak rate during the skimmer trials. Relative water velocities were higher at this time than during the morning test since the tow vessels were now heading downwind and needed to move faster to maintain steerage. Visually estimated leak rates were slightly higher (1 to 2 L/s) than previous (0.5 to 1 L/s). The evening leak rate data could be grossly underestimated as surface vessels to windward of the skimming vessel reported considerable numbers of emulsion balls in the sheen emanating from the skimming operation (Figure 21). It is possible that some or even all of this emulsion may have been driven beneath the boom by the cooling water discharge from the skimming vessel when it impinged on the oil in the boom (Figure 22).

3.4.3.2 Vikoma Ocean Pack

Figure 23 compares the leak rates and relative boom/water velocities for the period of time before, during and after the test of the Vikoma Ocean Pack. Wood chip drift time data for both tow vessels is available only for a 45 minute time period during the actual boom tests. Drift velocities from the tow vessel CCGS

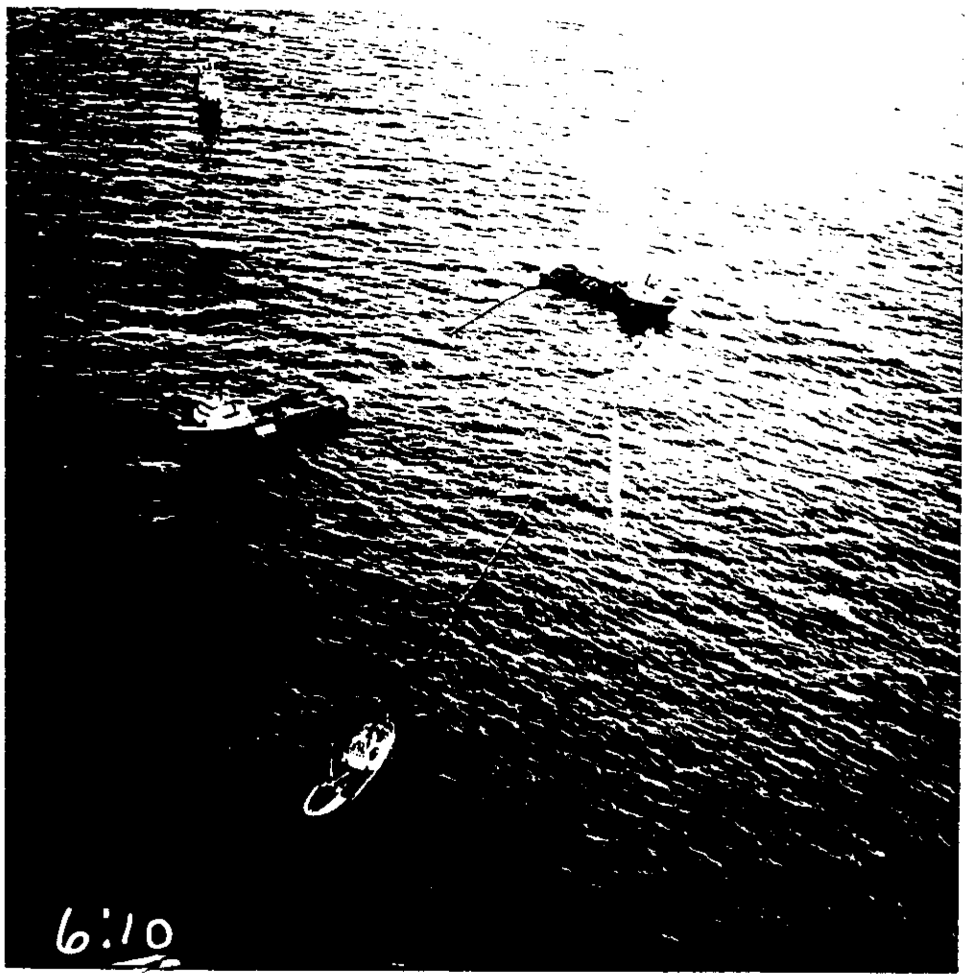


Figure 21 –Oil leakage from RO–BOOM during skimmer trials (compare sheen width to Figures 18 and 19)

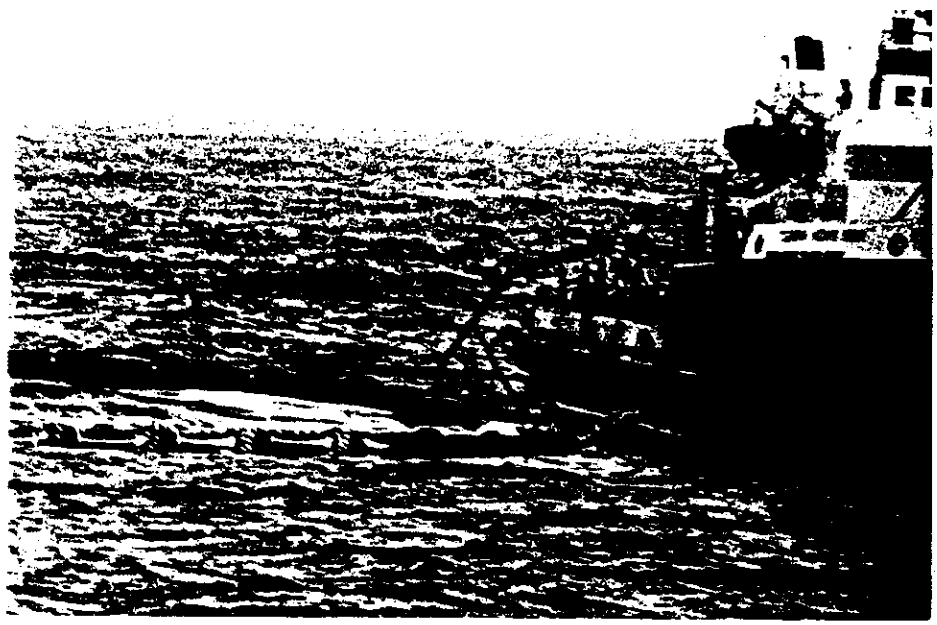
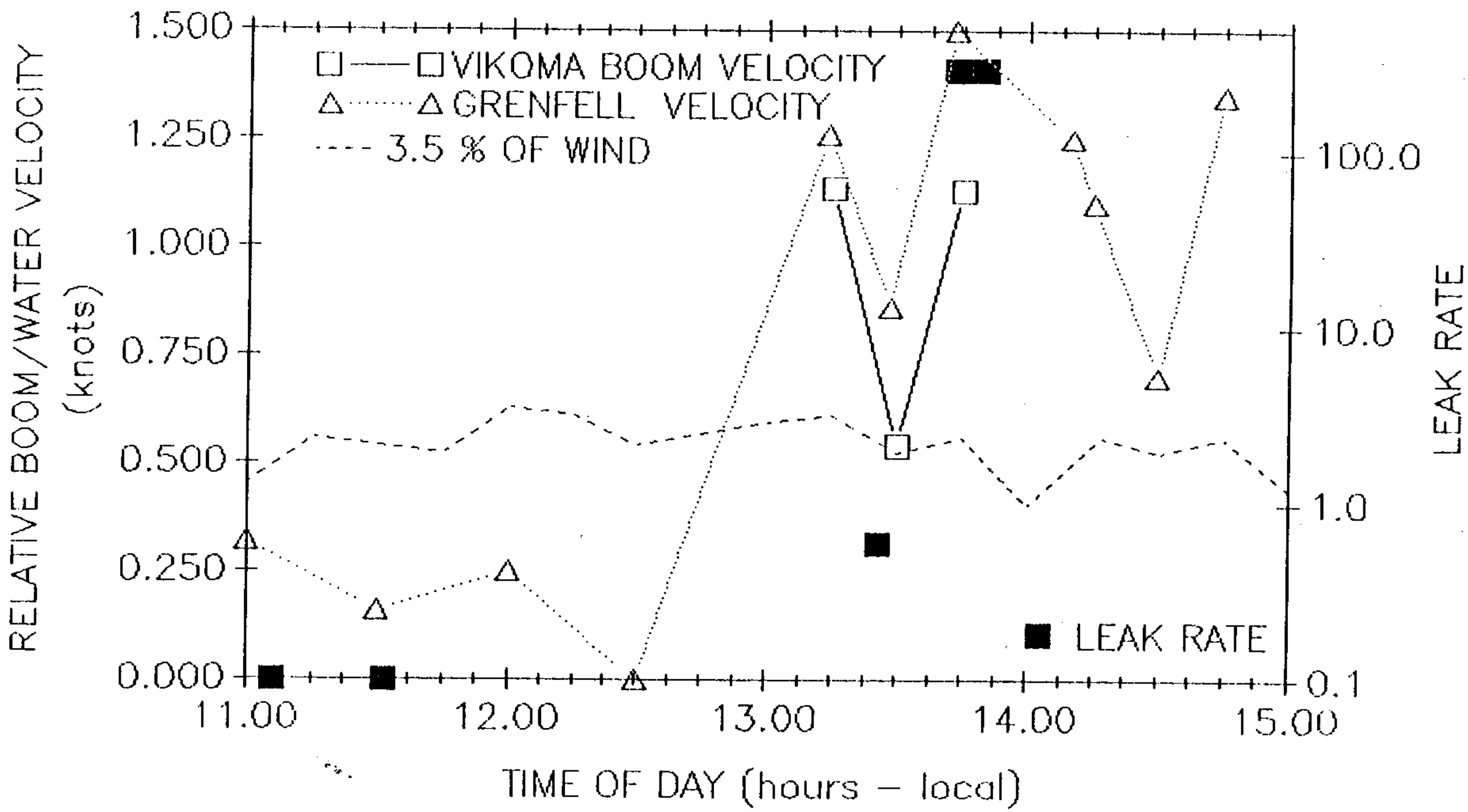


Figure 22 —Cooling water discharge from skimming vessel

FIGURE 23

VIKOMA OCEAN PACK LEAKAGE



Grenfell are plotted as an indicator of relative boom/water velocity before and after the test. However, as can be seen by comparing the Grenfell data with the calculated data from both vessels during the test period, there can be a considerable difference between the two. Prior to the test the Grenfell data is likely an underestimate of the actual velocity since during this period the other tow vessel was manoeuvring while the Grenfell maintained station. The roles reversed after the test and thus the Grenfell data for this period probably overestimates actual velocities.

Prior to the test, when the Vikoma boom contained only very small volumes of oil and velocities were low, the relative leak rate was on the order of 0.1 L/s (Figure 24). After intercepting the oil released from the OHMSETT instrumented boom at about 1330 the boom contained about 300 m^2 of oil with a reported visually estimated thickness of 2 to 5 cm translating to some 6 to 15 m^3 of oil. At this time the relative leak rate was 1.0 L/s (Figure 25) with a relative boom/water velocity of 0.25 m/s (0.5 knots).

The phenomenon of the Vikoma boom creating a small breaking wave at the juncture of the air and water chambers was observed (Figure 26). This likely causes some dispersion of oil beneath the boom but the rate would be very low. In booms full of oil this wave would likely be damped out. Previous tests with the Vikoma boom have reported a phenomenon where these waves prevent the slick from touching the boom; this was not observed in these trials. As the tow vessels manoeuvred the Vikoma Ocean Pack into a "J" configuration the relative velocity increased to in excess of 0.5 m/s (1 knot) and the ~~relative~~ leak rate increased dramatically to an estimated 200 L/s. Even this number may be conservative as visual estimates of the slick trailing the boom gave thicknesses of 3 to 4 mm or ~~relative~~ leak rates of 600 to 800 L/s. All the oil was lost from the boom pocket in a period of about 5 to 10 minutes. The cause of the oil loss was slick entrainment beneath the boom (Figure 27); little splashover and no boom sinking or wave topping was observed.

Subsequent to this the tow vessels repositioned heading downwind and recollected some thick oil; leak rate estimates are not available for this time period since it was impossible to distinguish oil emanating from the boom from the oil surrounding the area. During manoeuvring to reform a "J" at approximately 1430 for a second skimming attempt with the Vikoma boom, the relative boom water velocity

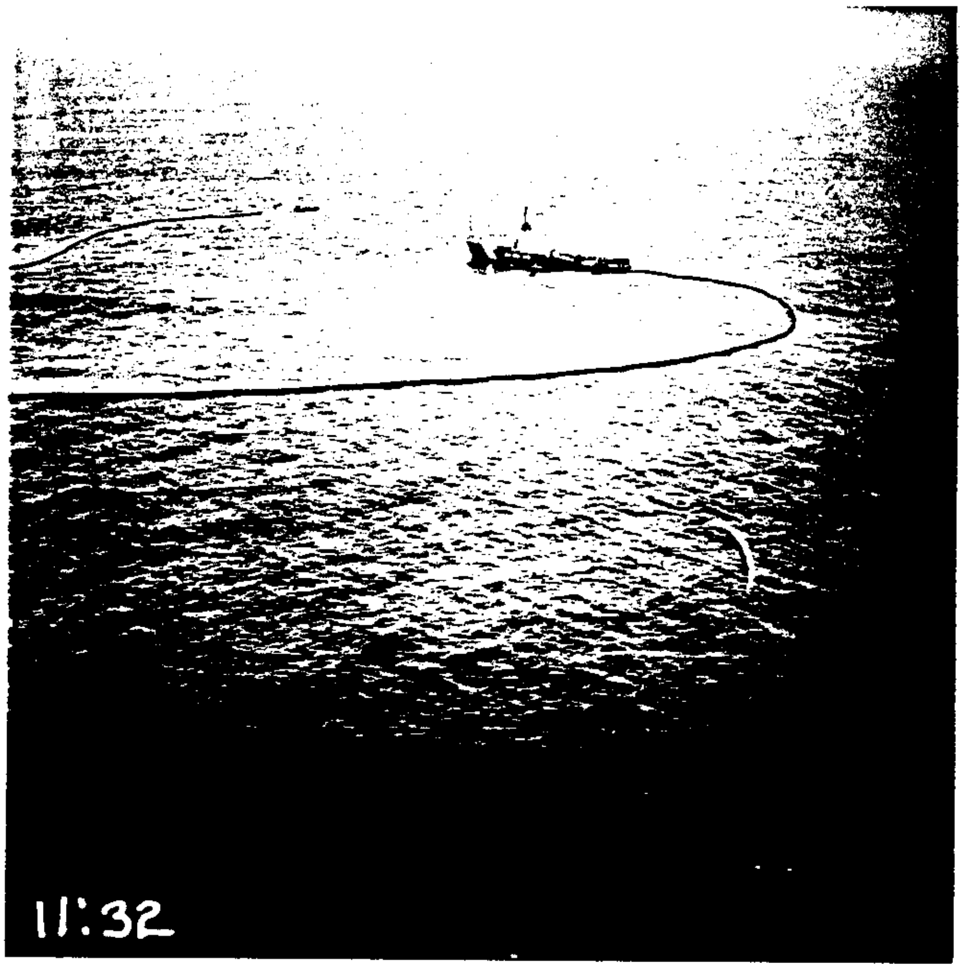


Figure 24 —Vikoma Ocean Pack leakage while containing very little thick oil

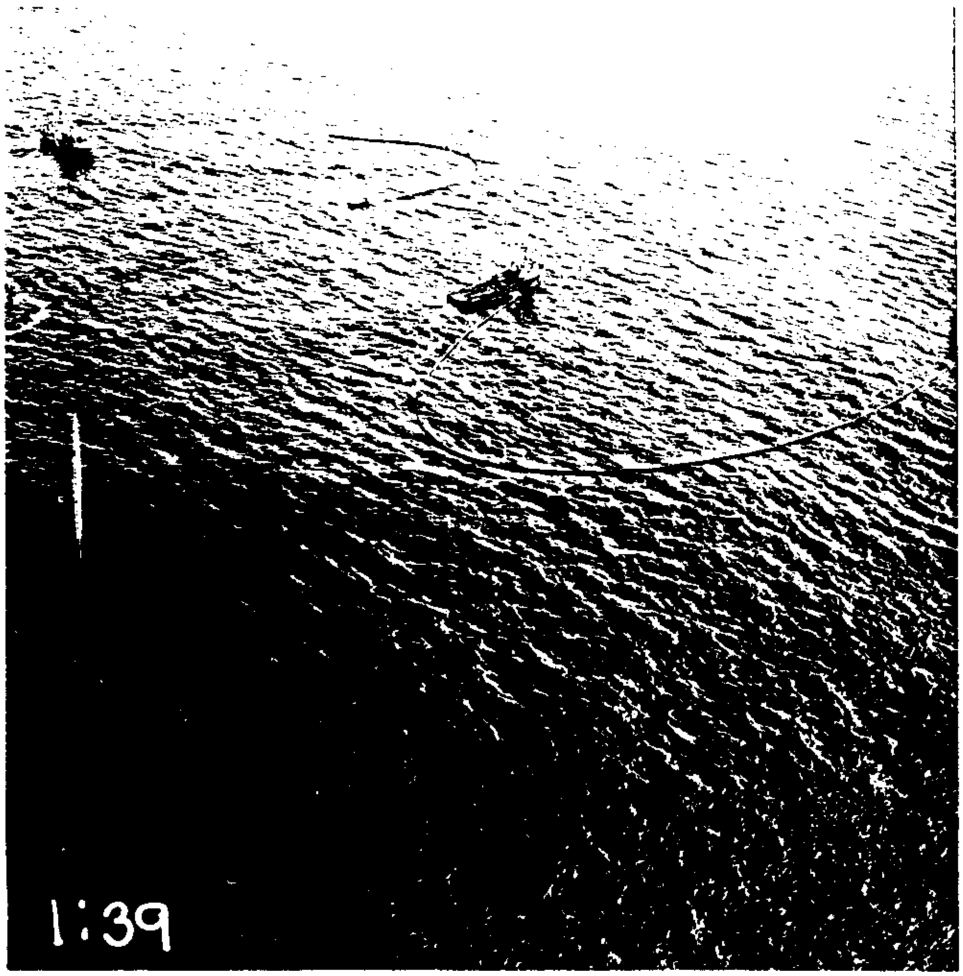


Figure 25 —Vikoma Ocean Pack leakage while containing thick oil; note area of thick oil.

Figure 26 —Small breaking waves at the waterline of the Vikoma Ocean Pack

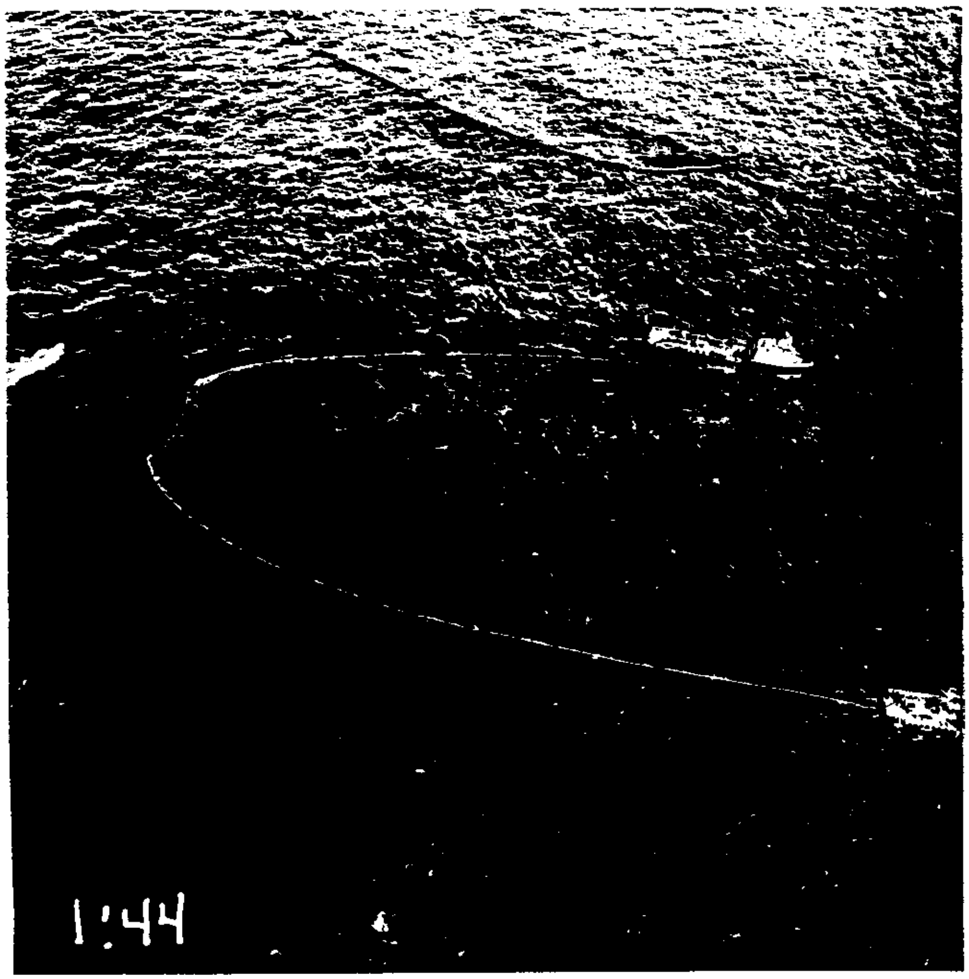


Figure 27 –Significant leakage of oil from Vikoma Ocean Pack. Relative boom/water velocity in excess of 0.5 m/s (1 knot)

exceeded oil containment limits and most of the oil was again lost. Following this second effort excessive strain was placed on the boom during manoeuvring causing the boom to lift from the water for as much as 10 m between wave crests on several occasions (see also Section 3.3.2).

3.4.3.3 Comparison

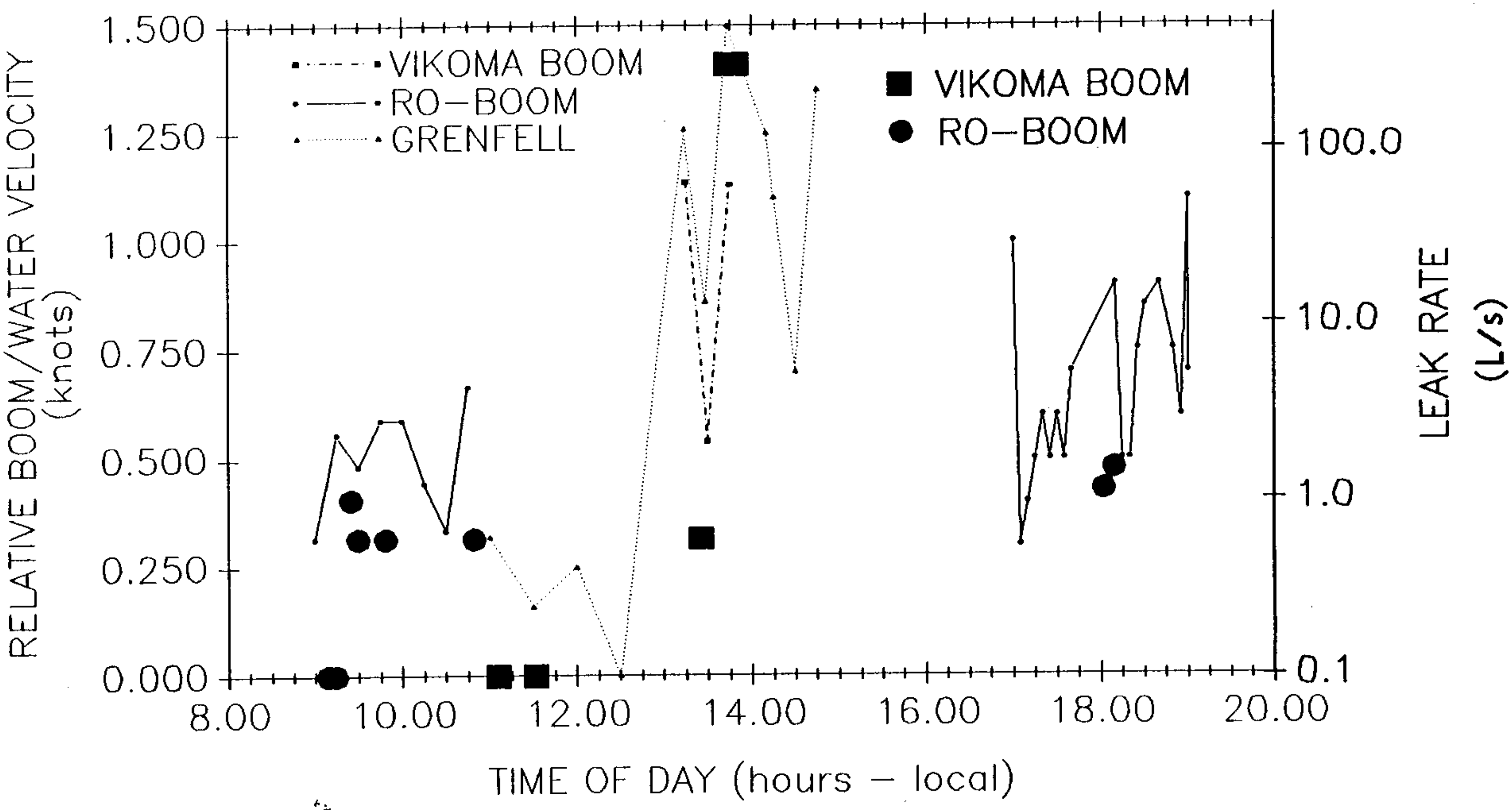
Figure 28 compares the leak rate and relative boom/water velocity data for both the RO–BOOM and the Vikoma Ocean Pack. Based on the estimated leak rates both booms performed equally well while maintaining station into the wind. The high loss rate from the Vikoma Ocean Pack during manoeuvring into the wind is related solely to the fact that, under the wind conditions at the site, any manoeuvring upwind caused relative boom/water velocities to exceed containment limits (0.5 m/s = 1 knot: Griffiths 1981). This is a factor independent of boom design. It is worth noting that the winds at the test site particularly during the afternoon and evening (15 to 20 knots), were near the maximum operating limits for any containment boom (18–20 knots: Beach et al. 1978) operating in a stationary upwind mode. Wind driven wave heights would also have continued to increase from the last observation of 1.3 ± 0.2 m at 1900 hrs, exceeding the upper limits for stationary boom containment (sea state 3–4 = 0.8 to 1.2 m average wave height: Solsberg 1986) by the end of the trials at 2036 hrs.

In general, the RO–BOOM seems slightly more prone to splashover in the upwind mode while the Vikoma boom seems slightly more susceptible to wave–induced dispersion losses.

Both booms were judged acceptable for use offshore; it is our opinion that the limiting wind and sea state for their use in containing slicks in a stationary mode, oriented into the wind would be only slightly higher than the conditions encountered during the trials. The booms could be used in still higher wind/sea conditions but only in a downwind mode (as was the case in the late afternoon and evening during the trials). This approach to extending the limitations of offshore containment and recovery (i.e., operating downwind) is effective when chasing individual slicks, as noted by the Action Commander in charge of the response to the Ekofisk Bravo

FIGURE 28

BOOM LEAKAGE RATES



blowout where the technique was used with the first Framo skimmer and a Nofi boom in seas of 2–2.5 m significant wave height (sea state 4) (Anderson et al. 1977).

3.5 SKIMMER PERFORMANCE

Due to the time required to collect sufficient oil for the skimming tests, deteriorating weather conditions, darkness, the addition of Elastol to the oil between skimmer tests, and mechanical difficulties with the Heavy Oil Skimmer, it was impossible to conduct thorough, comparative tests of the skimmers that would permit complete evaluation of their effectiveness on spills of waxy crude oils and with and without Elastol treatment. Regardless, valuable information was collected on the general performance of the skimmers.

Once sufficient emulsion had been contained within the pocket of the RO–BOOM (about 300 m^2, with an estimated thickness of 10 cm, or 30 m^3 = 7900 gal) the skimmer tests commenced. The results for each skimmer are discussed separately. Select raw data may be found in Appendix 5.

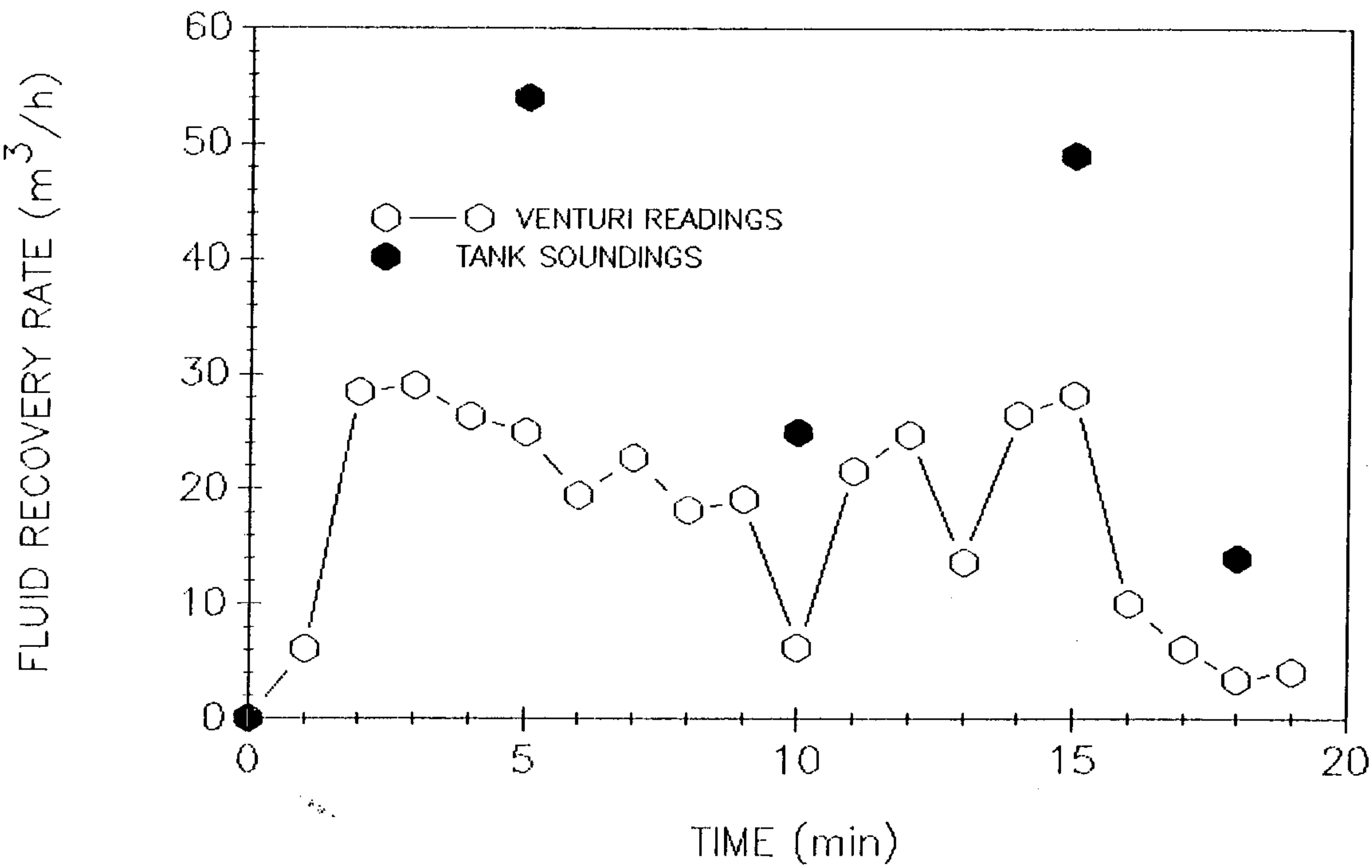
3.5.1 Framo ACW–400

3.5.1.1 Recovery Rates

Figure 29 shows the flowrates measured for the fluid recovered by the Framo ACW–400 skimmer. There is an obvious discrepancy between the results from the Venturi meter readings and the results from the tank soundings. Examination of the raw Venturi data (a sample is given in Appendix 5) shows that in many of the 3-second data sampling periods, the maximum recorded value is the upper limit of the equipment, thus the 3 second recorded averages, and the 1 minute averages calculated for Figure 29 are underestimates of actual flow conditions. For this reason the performance assessment of the Framo ACW–400 skimmer is based on tank sounding data only. Over the 23 minute deployment (including 18 minutes of operation) the Framo recovered some 11.6 m^3 (3065 gal) of fluid at an average recovery rate of 39 m^3/hr (172 gal/min). After accounting for 5 m^3 (1320 gal) of free water recovered

FIGURE 29

FRAMO ACW-400



the emulsion recovery rate was 22 m^3/hr. Subtracting the 2.5 m^3 (660 gal) of water in the emulsion recovered yields an oil recovery efficiency for the Framo ACW–400 of 35% (14 m^3/hr = 60 gal/min). The maximum fluid recovery rate recorded was 54 m^3/hr (240 gal/min).

3.5.1.2 General

For the first few minutes of its test the Framo ACW–400 (Figure 30) was incorrectly positioned at the outer edge of the oil and was collecting primarily water. During the last few minutes of its test, Elastol was added to the slick; this had no measurable or observable effect on its performance probably because the Elastol had not had sufficient time to act on the oil. During its period of operation it was noted that waves frequently flooded the collection well of the Framo ACW–400 skimming head resulting in the recovery of large volumes of water. Based on observations of the other two skimmers tested in a free–floating mode, it is possible that the oil recovery efficiency of the Framo ACW–400 could have been greatly improved by operation in a free–floating mode rather than attached to the hydraulic arm. Observations of the action of the skimmer head suggest that the motion–compensation in the Framo ACW–400 hydraulic arm can adequately deal with the pitch and roll of the skimming vessel but cannot compensate for shorter period wave action.

Visual observation of the discs during the skimmer test indicated that the waxy oil was not adhering well; because of time constraints and deteriorating weather conditions ~~unfortunately~~ the Framo ACW–400 was not redeployed and tested after the Elastol had acted on the oil and no better comparison~~s~~ can be made.

3.5.2 Heavy Oil Skimmer

The heavy oil skimmer was deployed four times: once into the collapsed "J" formed by the Vikoma Boom and three times during the skimmer tests utilizing the RO–BOOM. Only during the last deployment, in emulsion to which Elastol had been added, was recovery observed. Unfortunately, this last deployment was cut short when the discharge hose from the skimmer burst.

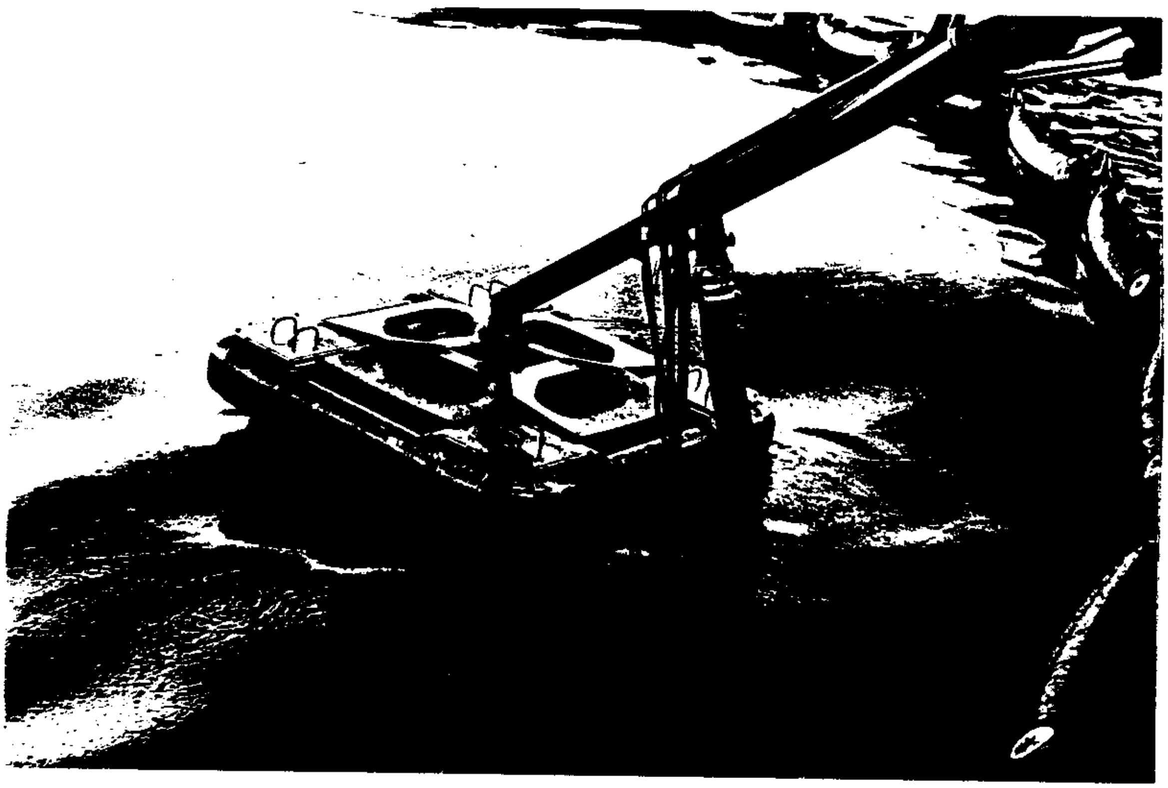


Figure 30 —Framo ACW—400 skimmer

3.5.2.1 Recovery Rates

During its second deployment (the first deployment into untreated oil contained in the RO-BOOM) no recovery of the waxy oil was recorded. It was observed that the oil was not adhering to the fabric surface of the drums. Figure 31 shows the Venturi data that was collected during the fourth and last deployment of the Heavy Oil Skimmer in Elastol-treated oil, prior to the failure of the discharge hose, and the termination of the trials due to darkness and deteriorating weather.

No tank sounding data is available since the discharge hose burst before the recovered fluid filled the hose to the tank. Over the five minute test period the skimmer recovered an average 11 m^3/hr (50 gal/min) of Elastol-treated fluid. The maximum fluid recovery rate was 20 m^3/hr (90 gal/min). It should be noted that this recovery rate was obtained with only one drum of the Heavy Oil Skimmer fully operational; the absorption fabric on the other had been damaged in the previous deployment and only 30-40% of this drum was covered. Based on one sample of unknown origin the oil recovery factor was 35% (4 m^3/hr = 20 gal/min). No information on the amount of free water vs. water contained in the emulsion is available for this sample.

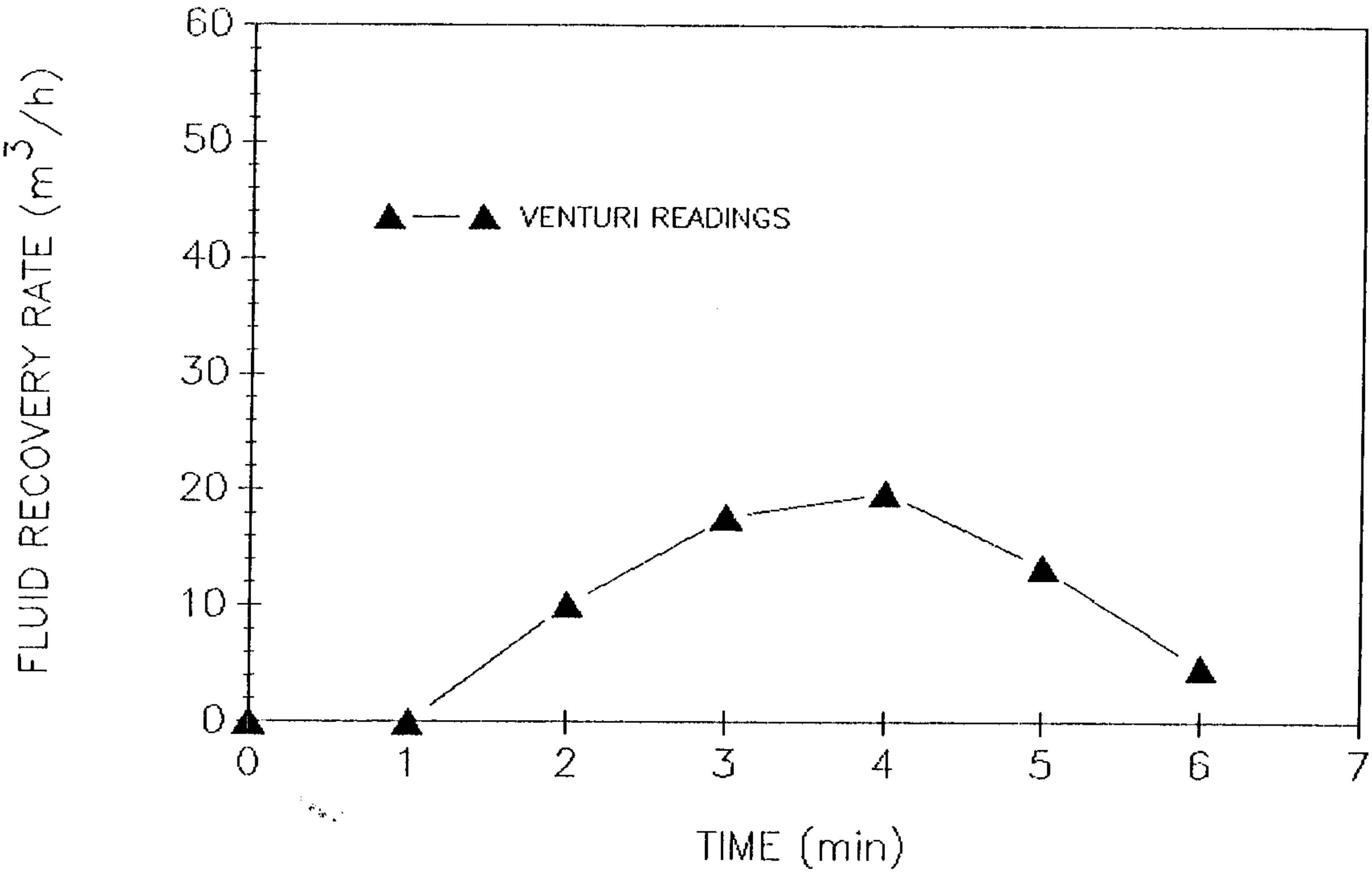
3.5.2.2 General

During its second deployment in the slick prior to Elastol addition, it was observed that very little oil was adhering to the drums of the Heavy Oil Skimmer (Figure 32). In comparison, operation of the drums in oil to which Elastol had been added resulted in a layer of oil 1 cm (0.4 inch) or thicker adhering to the drums. One observer noted that the skimmer operated as well or better in the reverse rotation mode (pushing the oil down beneath the drums and up onto the scrapers) as it did in the normal rotation mode (pulling oil up over the top of the drums and down onto the scrapers).

For the first two deployments of the Heavy Oil Skimmer it was attached to the Framo unit hydraulic arm by means of a universal joint (Figure 32). This caused excessive pitch and roll of the skimmer, causing complete submergence of one roller

FIGURE 31

HEAVY OIL SKIMMER



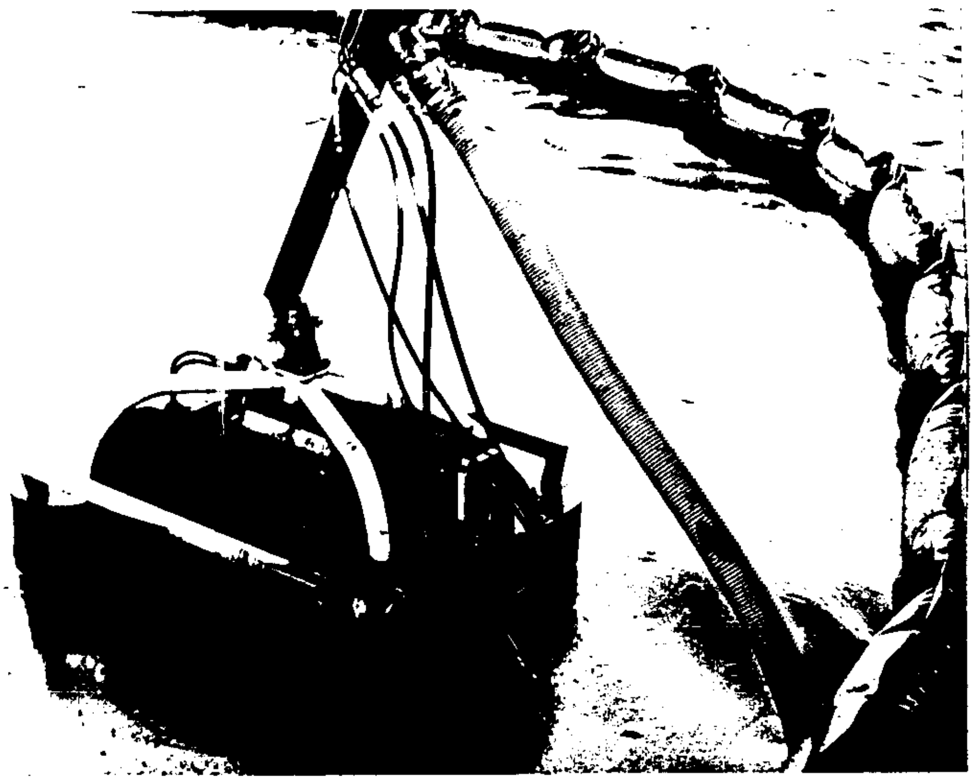


Figure 32 – Heavy Oil Skimmer operating prior to Elastol addition. Note very little oil adhering to drums.

on one occasion. For the third deployment, the universal joint was replaced by a short length (0.6 m) of rope. This allowed the skimmer to operate in a free-floating mode and follow the waves much better. Unfortunately, the short rope length required that the hydraulic arm remain in close proximity to the skimmer and, during one roll of the skimming vessel the hydraulic arm hit one drum and tore the fabric. For the last deployment the heavy oil skimmer was attached to the hydraulic arm by a much longer chain.

During the first deployment of the Heavy Oil Skimmer (into the pocket of the Vikoma boom) the snagging of the skimmer by the boom (Figure 33) caused the failure of a hydraulic hose; this was easily repaired. The third deployment of the Heavy Oil Skimmer was unsuccessful because a bolt had fallen into the pump intake; this was quickly rectified.

Overall, the tests of the Heavy Oil Skimmer were only partially satisfactory

Overall the tests of the Heavy Oil Skimmer (HOS) were satisfactory since although it was not possible to obtain quantified performance data for the elastol treated oil, valuable handling experience was gained under realistic offshore conditions, correctable design deficiencies were identified and the inability to recover waxy oil was established.

3.5.3 GT-185

3.5.3.1 Recovery Rates

Figure 34 shows the fluid recovery rates measured with the Venturi meter and tank soundings for the GT-185 skimmer during its ~~test~~ deployment. In this case, since the fluid recovery rates were lower than during the Framo ACW-400 test, the two ~~sets of data~~ Venturi readings correspond well. Over the 29 minute test period the GT-185 collected a total of 9.4 m^3 (2480 gal) of emulsion at an average recovery rate of 19 m^3/hr (85 gal/min). After accounting for 5 m^3 (1320 gal) of water in the emulsion recovered (no free water was measured), the oil recovery efficiency was 46% (9 m^3/hr = 40 gal/min).

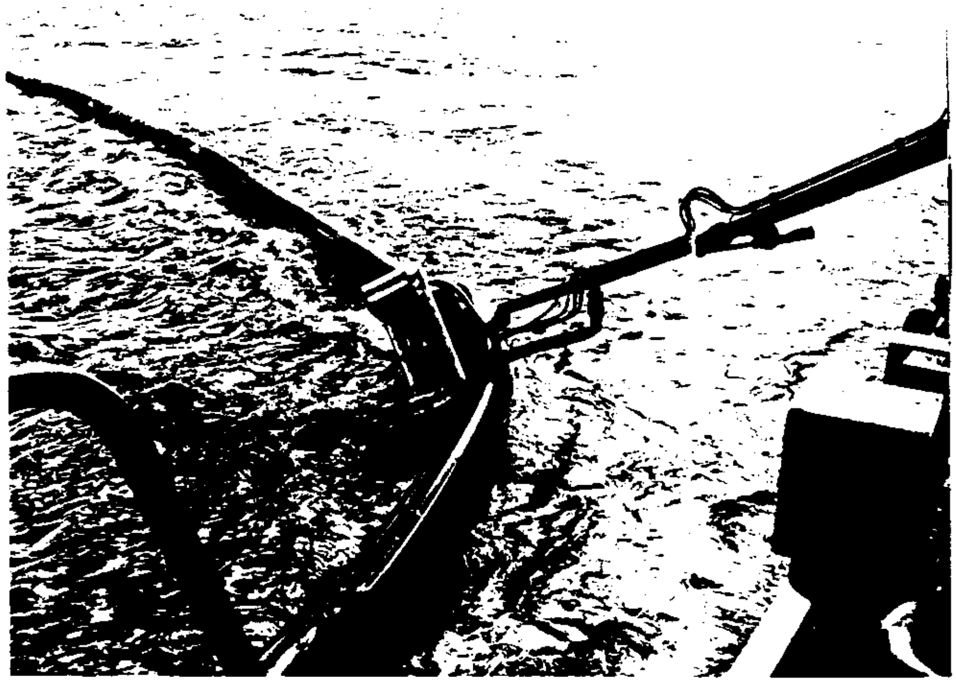
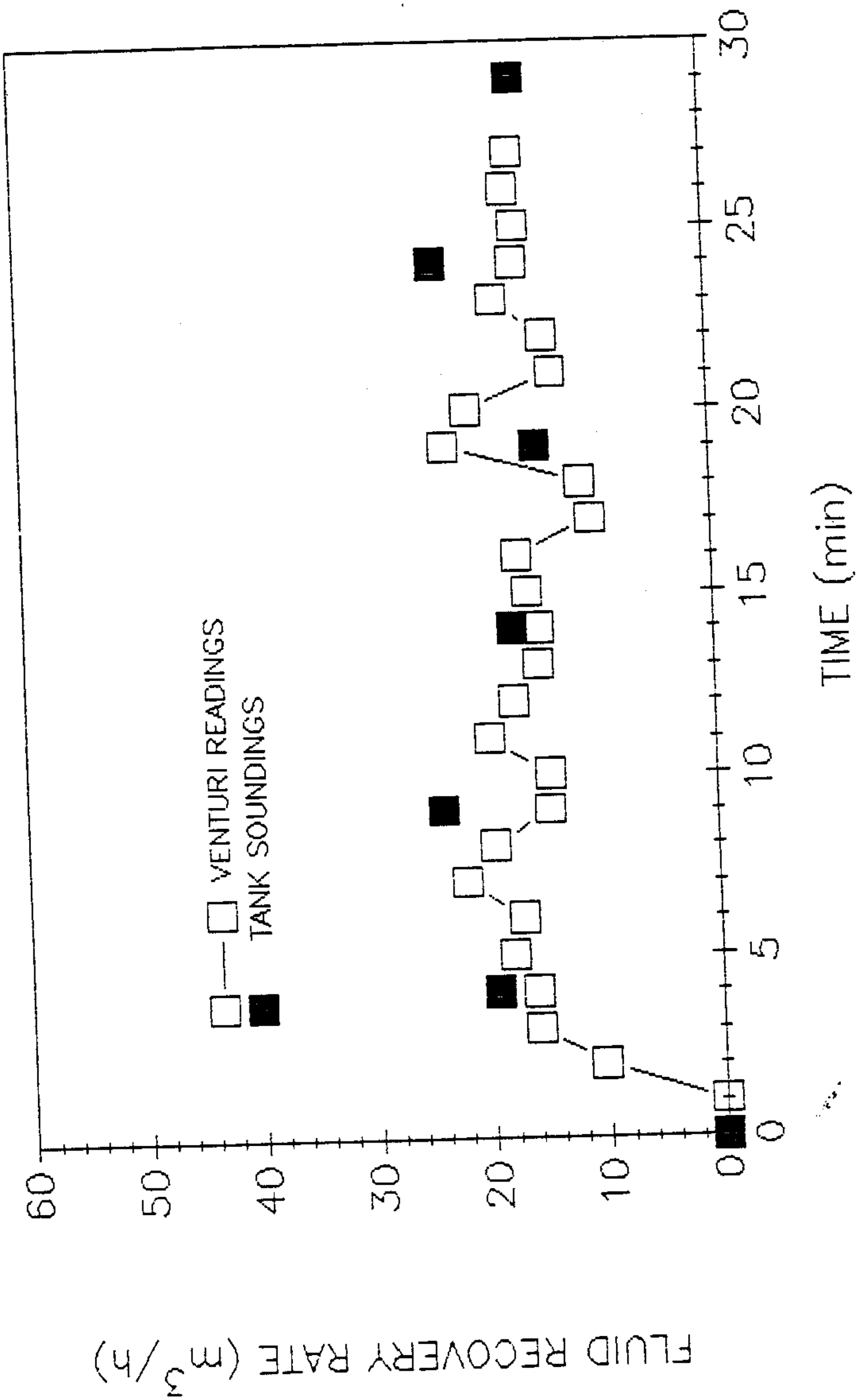


Figure 33 – Heavy Oil Skimmer snagged on Vikoma Ocean Pack boom

FIGURE 3b
GT–185



The maximum fluid recovery rate measured (over a 5 minute period) was 24 m^3/hr (105 gal/min).

3.5.3.2 General

Since the ~~test~~ use of the GT-185 skimmer took place subsequent to the addition of Elastol to the slick, no evaluation of the effectiveness of this skimmer for the recovery of waxy crude oils can be made (this was not an objective of the trials in any case). In general the skimmer operated without incident ~~during its test~~ (Figures 35 and 36) and, due to its free-floating mode, followed the waves very well, as evidenced by the absence of free water in the recovered product. On one occasion the skimmer did snag on the boom when the skimming vessel drifted slightly off station, but the skimmer was undamaged.

The ~~Elastol rendered the oil viscous resulting~~ increased viscosity of the Elastol treated oil resulted in high pressure drops in the skimmer discharge and ~~perhaps reducing~~ may have reduced the performance of this device.

3.5.4 Comparison

It is impossible to draw quantitative conclusions from a comparison of the skimmers tested. The Framo ACW-400 was tested prior to Elastol being added to the slick, the GT-185 was ~~tested~~ [illegible] after and, although the Heavy Oil Skimmer was tested both before and after Elastol addition the device was operating with one damaged drum during its final test. Regardless, a presentation of ~~the~~ available data may prove useful for future studies.

Table 2 and Figure 37 compare the overall average performance measured for the three skimmers. The Framo ACW-400 achieved the highest fluid recovery rate (39 m^3/hr = 170 gal/min) but much of this was free water. Discounting ~~this,~~ the free water the Framo recovered 22 m^3/hr (95 gal/min) of emulsion or an equivalent 14 m^3/hr (60 gal/min) of oil. Had the skimmer followed the waves better and been positioned in the thick portion of the oil for the entire test it is possible that the measured oil recovery efficiency (35%) would have been higher, but not ~~likely~~ probably dramatically so. The poor adherence of

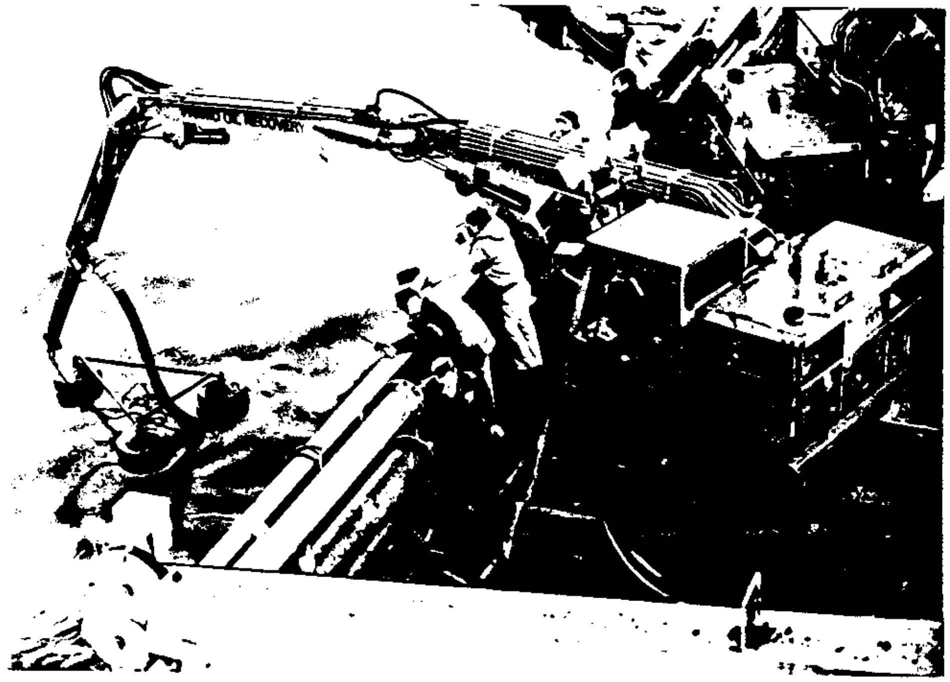


Figure 35 –GT–185 skimmer recovering emulsion treated with elastol

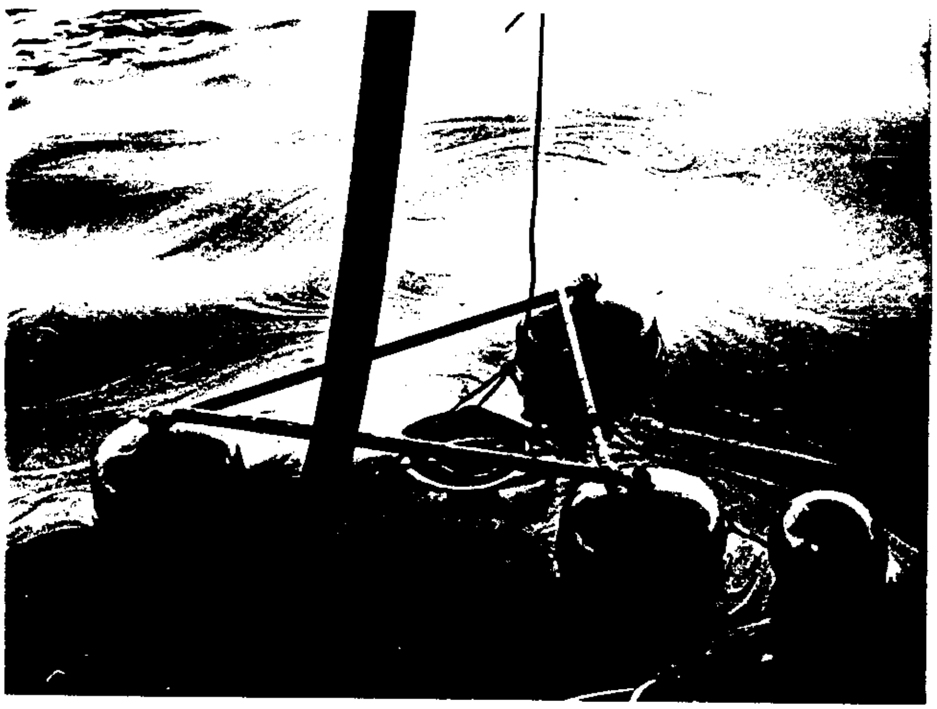


Figure 36 –Close up of above

TABLE 2

OVERALL SKIMMER PERFORMANCE

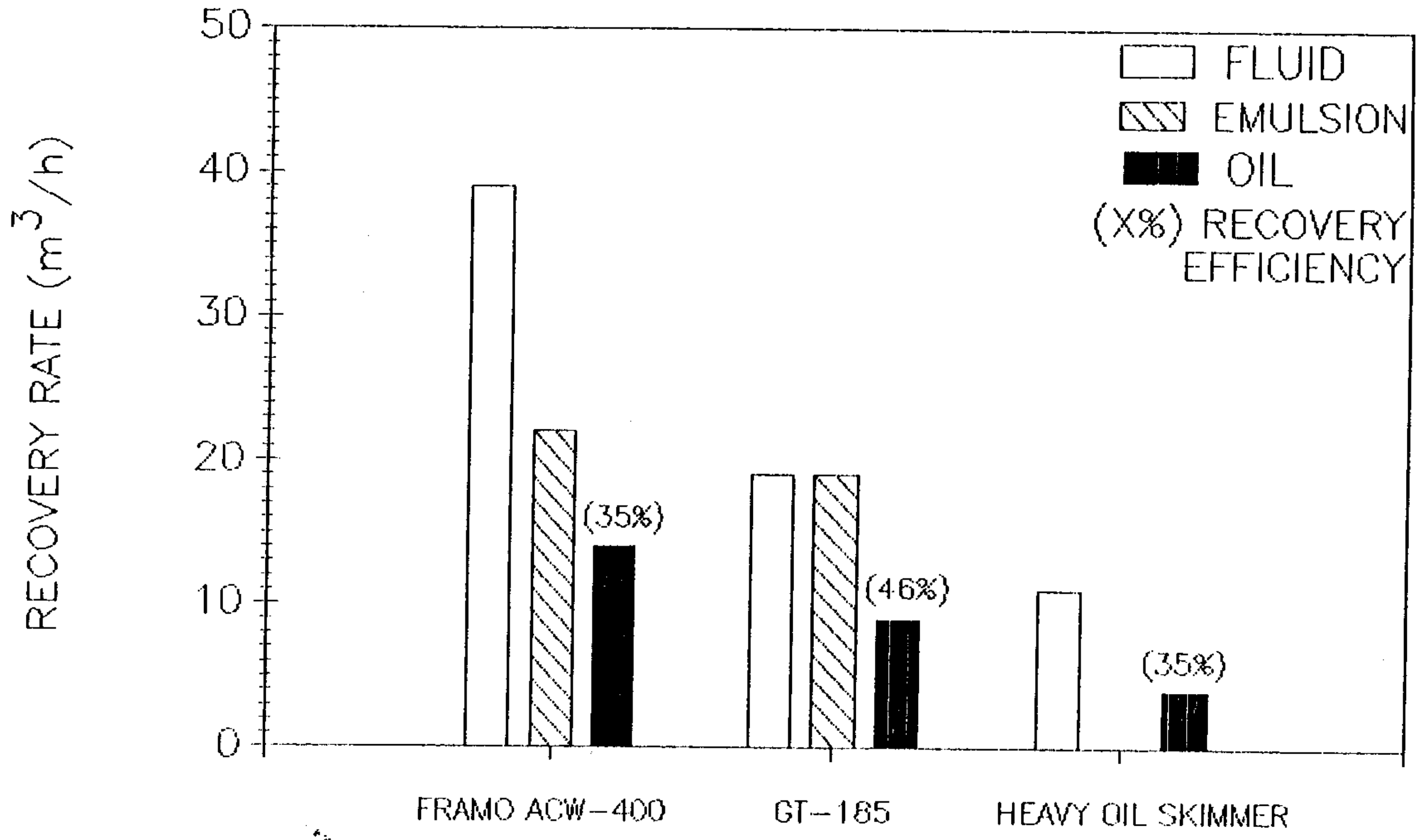
SKIMMER	VOLUMES RECOVERED				RECOVERY RATE		
	FLUID (m^3) [U.S. gal]	FREE WATER (m^3/vol %) [U.S. gal]	EMULSIFIED WATER (m^3/vol %) [U.S. gal]	OIL (m^3) [U.S. gal]	FLUID (m^3/hr) [U.S. gal/min]	OIL (m^3/hr) [U.S. gal/min]	EFFICIENCY (vol %)
FRAMO ACW–400	11.6 [3065]	5.0/43 [1320]	2.5/38 [660]	4.1 [1085]	39 [170]	14 [60]	35
GT–185+	9.4 [2485]	0/0	5.0/54	4.4 [1160]	19 [85]	9 [40]	46
HEAVY*+ OIL SKIMMER	0	0	0/65*	0	11* [50]	4* [20]	35*

\+ ~~tested in~~ Elastol–treated oil

* based on analysis of 6 minutes of venturi data and one oil sample only

FIGURE 37

COMPARISON OF RECOVERY RATES



waxy oils and their emulsions to the oleophilic discs of this skimmer type was apparent both visually and in the relatively low emulsion and oil recovery rates (previous tests with non–waxy oils have yielded recovery rates in the 50 to 100 m^3/hr range). Most of the oil recovered appeared to be as a result of the oil slopping over into the sump i.e., the skimmer was operating as a weir device.

In comparison, the GT–185 with a fluid (and emulsion, since no free water was collected) recovery rate of 19 m^3/hr (85 gal/min) and an oil recovery efficiency of 46% seemed to be operating near capacity. This was evident from the occasional flooding of the collection well. It is possible that the performance of this skimmer was reduced by the addition of Elastol to the slick; the increased viscosity of the emulsion would reduce both flowrates over the weir lip and pumping rates.

The Heavy Oil Skimmer test prior to the addition of Elastol to the oil resulted in no measurable recovery. The measured recovery rate of the Heavy Oil Skimmer (11 m^3/hr = 50 gal/min) in Elastol–treated oil is likely an under indication ~~underestimate~~ for the performance of the skimmer for two reasons: first, one drum of the skimmer had been damaged resulting in the loss of 60 to 70% of the oleophilic fabric on its surface and second, it is likely that debris found blocking the Venturi throat reduced the pump discharge rate (the resulting backpressure seems the most likely cause of the subsequent failure of the discharge hose) and may have affected differential pressure readings. It is unclear whether this latter factor would result in under– or ~~overestimates~~ of flowrate.
over indications

Based on a visual comparison of the thickness of emulsion adhering to the Heavy Oil Skimmer drums before and after the addition of Elastol to the slick and a comparison of recovery rates (0 vs 11 m^3/hr) it is apparent that the Elastol dramatically improved the performance of this skimmer with waxy oil. This is not surprising since the skimmer was designed to recover heavy, viscous oil slicks such as those resulting from spills of Bunker C.

In summary, due to the non–sticky nature of the waxy crude oil used for these tests, the skimmers depending on an oleophilic surface ~~as the~~ collection ~~principle~~ fared poorly. Those utilizing a weir proved more suited to the task. The addition of Elastol to the oil improved the oil's adhesion to the Heavy Oil Skimmer dramatically, but may have detracted from the performance of the weir-type GT-185 skimmer by increasing the oil's viscosity and thus ~~flow~~ altering flow over the weir and through discharge hoses. This ~~latter observation~~ possibility is important since it is known that some oils discovered on the Grand Banks are much waxier than the test crude and thus will likely be present as very viscous semi-solid mats or droplets rather than the comparatively fluid oil used for these tests (S.L. Ross and DMER 1987). Weir skimmers would likely perform less effectively in the more waxy oils, recovering less oil and more water (S.L. Ross and Hatfield 1986).

4.0 OIL FATE, BEHAVIOUR AND EFFECTS

This section describes the observed behaviour (spreading, drift, evaporation and emulsification) of the oil and the predicted fate of the oil remaining on the sea surface after the trials.

4.1 SPILL BEHAVIOUR

Slick spreading was determined from aerial visual estimates of slick size. Several samples (pre–spill, Framo ACW–400 discharge – i.e., pre Elastol, and GT–185 discharge – i.e., post Elastol) were also obtained and analysed for physical properties (density, viscosity and water content) and evaporative loss.

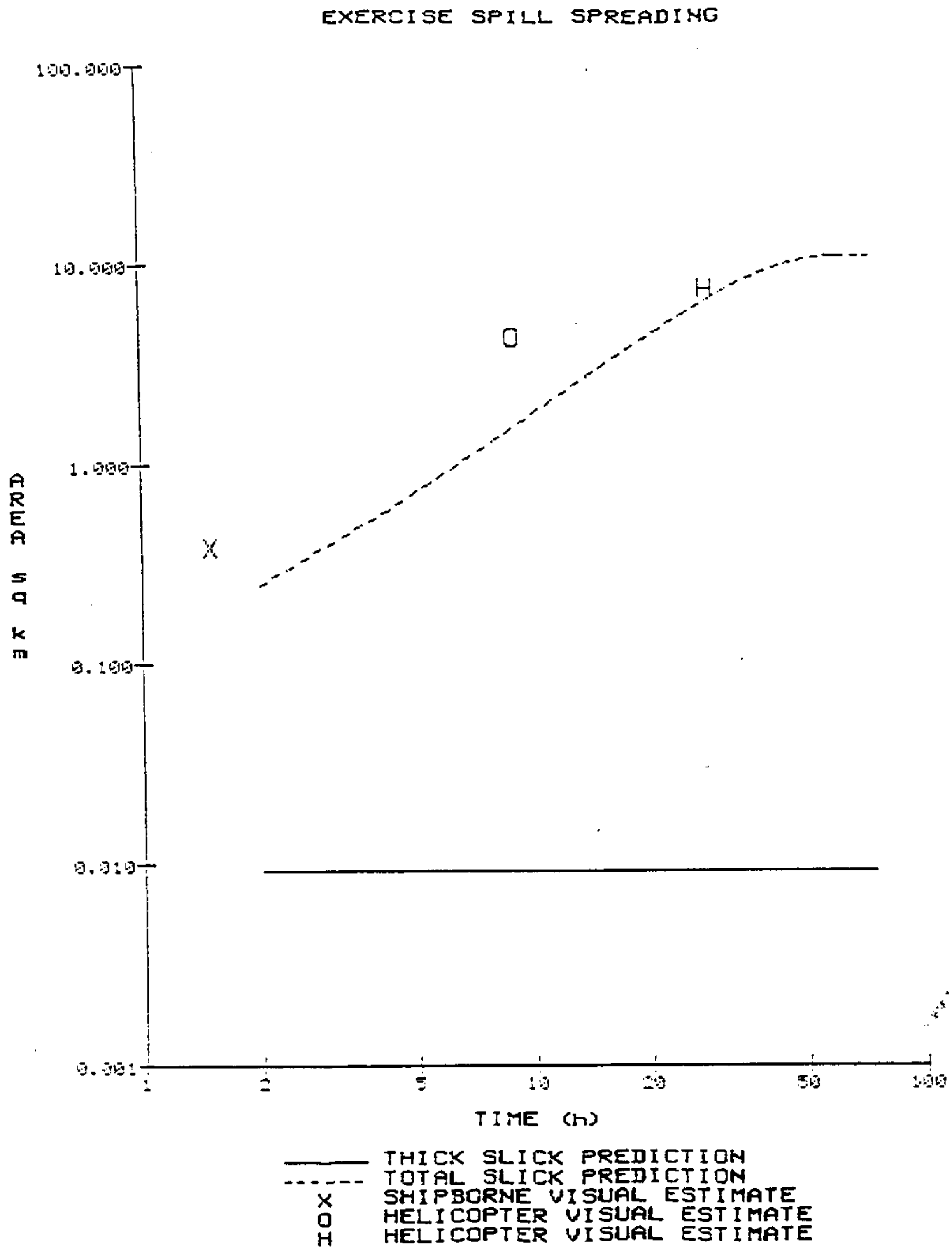
4.1.1 Spreading

Figure 38 compares the slick areas estimated at various times after the oil release to the predicted spreading curve for a typical Hibernia crude oil (modified to reflect the test crude's properties). In general the observed areas are in agreement with those predicted; the thick slick area is not predicted to increase since the weathered oil's pour point exceeds the ambient temperature (i.e., the oil forms gel). Individual thick patches or particles of oil and emulsion would, of course, disperse over the sea surface under the influence of horizontal surface turbulence and eventually form windrows. This was observed during the aerial reconnaissance the day after the trials.

4.1.2 Slick Drift

Figure 39 shows the recorded location of the contained portion of the slick at various times throughout the trials, based on ship's LORAN–C positionings, and the location of the slick the following day as determined during an overflight on

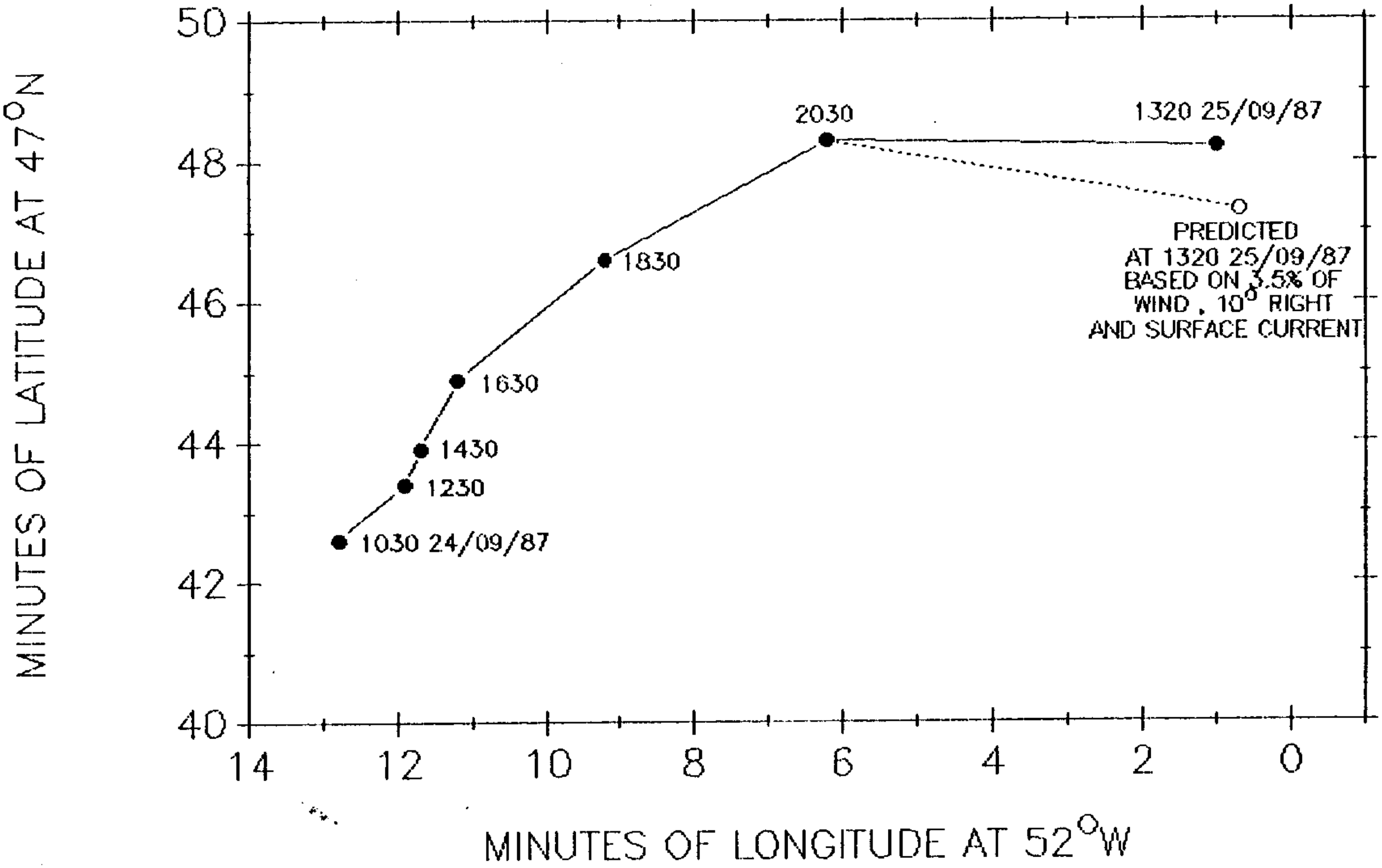
FIGURE 38



EXERCISE SPILL SPREADING
100.000
10.000
1.000
0.100
0.010
0.001
AREA sq km
1
2
5
10
20
50
100
TIME (h)
X
O
H
THICK SLICK PREDICTION
TOTAL SLICK PREDICTION
X SHIPBORNE VISUAL ESTIMATE
O HELICOPTER VISUAL ESTIMATE
H HELICOPTER VISUAL ESTIMATE

FIGURE 39

SLICK POSITION



September 25th. Also shown is the predicted slick drift from 2030 on September 24th to 1320 on September 25th (prior to this the slick was being towed). The predicted drift was based on the vector sum of 3.5% of the measured wind at St. John's Airport with a 10° clockwise Coriolis deflection and the reported residual current for the general area (30 cm/s to the south). Based on the general wind conditions recorded at St. John's Airport on the following two days (see Appendix 4) a continued general ~~westerly~~ easterly drift of the remaining oil would be predicted at rates between 13 and 35 km/day.

4.1.3 Oil Weathering and Property Changes

Table 3 shows the density, viscosity, water content and evaporative loss for each of the samples of the test oil. The lower water content of the GT–185 sample as compared to the Framo ACW–400 was due to the fact that the former sample had separated during shipment while the latter had not. It is not clear whether or not this was related to either Elastol addition or prior sample handling procedures. The effect of Elastol addition in increasing oil viscosity is apparent. Both samples from the skimmers showed an evaporative loss of 14%. This relatively slow evaporation is typical of waxy oil spills.

TABLE 3

PROPERTIES OF WEATHERED OIL AT 12°C

SAMPLE DESCRIPTION	EVAPORATIVE LOSS (vol %)	EMULSION DENSITY (kg/m^3)	EMULSION VISCOSITY (mPas)	(cSt)	WATER (mass %)
PRE–SPILL	0	839.8	20	24	0.0
FRAMO ACW–400 RECOVERY	14	954.3	2000	2100	37
GT–185 RECOVERY	14	898.7	6250	6950	6

4.2 PREDICTED OIL FATE

Figures 40 and 41 show the computer predictions (S.L. Ross and DMER 1987) for the fate of a Hibernia crude oil, with properties modified to reflect those of the test oil, at wind speeds of 7 and 10 m/s respectively (15 and 20 knots) representing the low and average wind speeds recorded at the test site and at St. John's Airport on the three days following the trials. Figure 40, for a wind speed of 7 m/s (the low ~~average~~ during the trials), also contains the measured data on pre–Elastol–addition slick properties. The less–than–predicted values for emulsion water content (and thus density and viscosity) may be an artifact of sampling procedures or may indicate that the oil was not emulsifying as rapidly as predicted and thus dispersing faster than predicted. The measured value for volume evaporated matches the prediction.

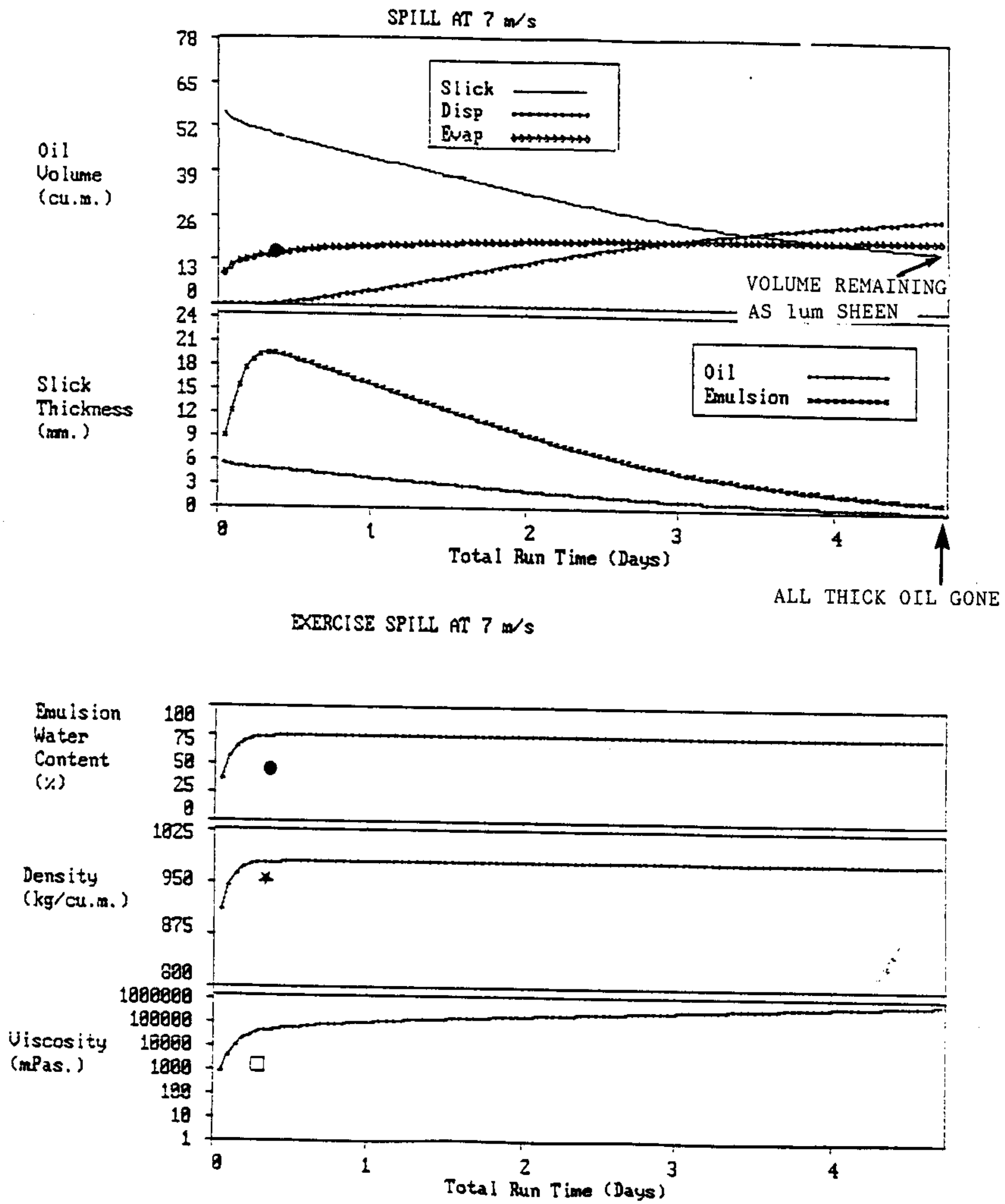
An overflight was conducted the day following the tests in order to trace any remaining slick. It was located at position 47 48.2 N, 52 01 W, as determined by the helicopter pilot. The slick was about 4.5 mi long by 1 mi. wide and elliptical in shape. Heavy patches of emulsified brown oil were apparent in the leading edge and at the tail. The main slick was predominantly made up of silver sheen and windrows of thicker brown oil stretched throughout the central slick region, from beginning to end. An Orion tracking buoy placed in the slick at the end of the skimmer tests was located by sight in the center of the slick. The computer model predicted slick survival times of 5 and 3 days respectively for the selected representative wind speeds of 7 and 10 m/s. These predictions are consistent with the aerial observations.

A ship dispatched to the reported spill location found the slick but was unable to find an area of thick oil in order to collect a sample.

4.3 EFFECTS

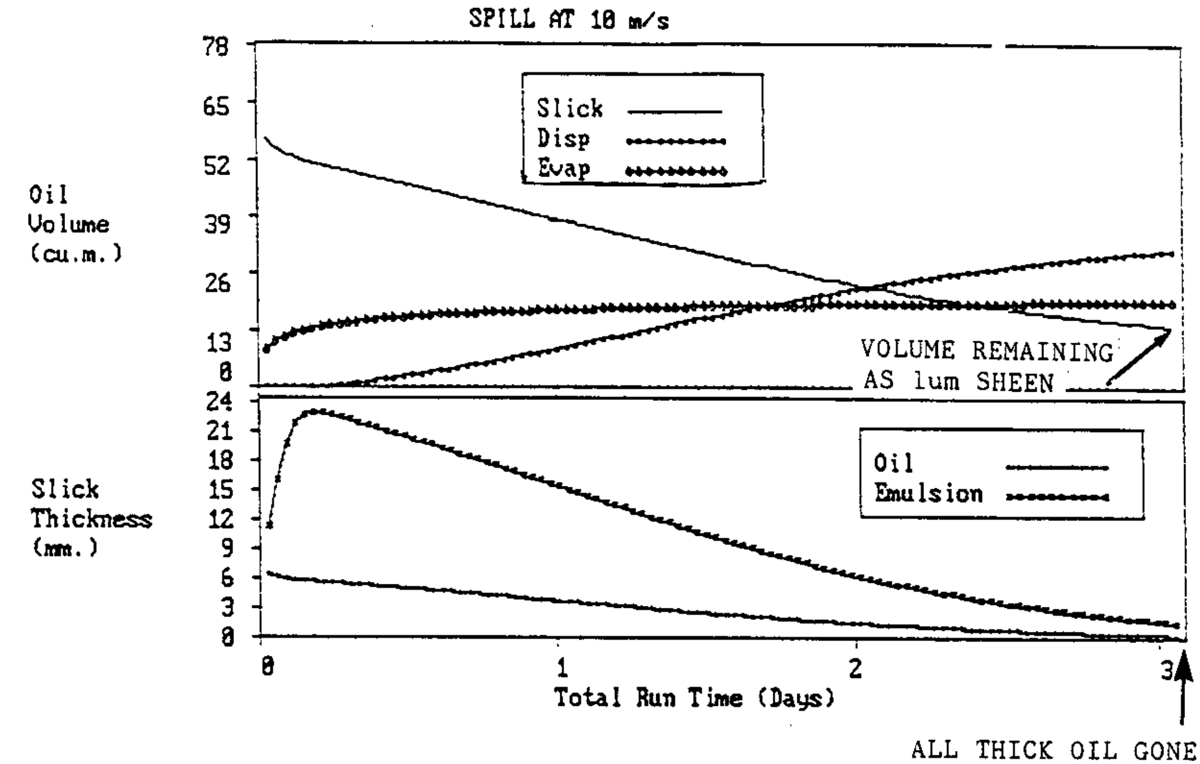
A representative of the Canadian Wildlife Service attended the trials to observe any animals in the area. The following is a summary of his observations at the test site (R. Elliot personal communication).

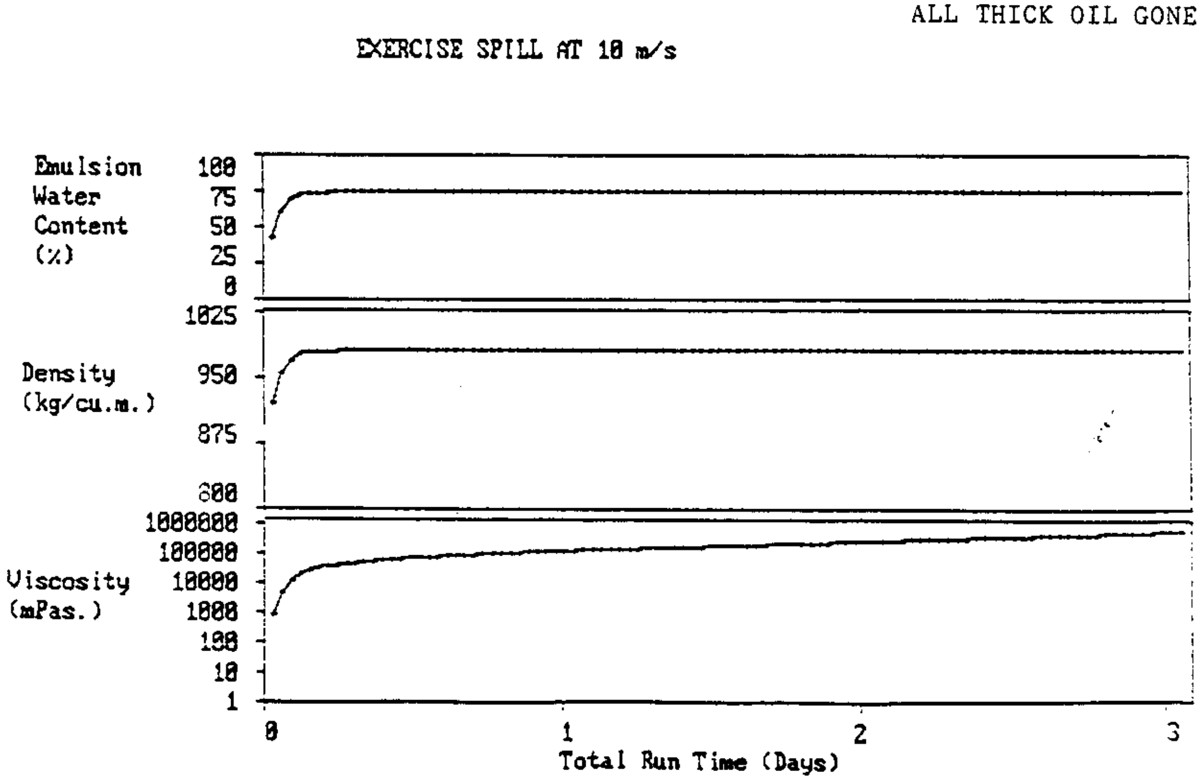
FIGURE 40



SPILL AT 7 m/s
Oil Volume (cu.m.)
78
65
52
39
26
13
0
Slick
Disp
Evap
VOLUME REMAINING AS 1um SHEEN
Slick Thickness (mm.)
24
21
18
15
12
9
6
3
0
Oil
Emulsion
0
1
2
3
4
Total Run Time (Days)
ALL THICK OIL GONE
EXERCISE SPILL AT 7 m/s
Emulsion Water Content (%)
100
75
50
25
0
Density (kg/cu.m.)
1025
950
875
800
Viscosity (mPas.)
1000000
100000
10000
1000
100
10
1
0
1
2
3
4
Total Run Time (Days)

FIGURE 41


SPILL AT 10 m/s
Oil Volume (cu.m.)
78
65
52
39
26
13
0
Slick
Disp
Evap
VOLUME REMAINING AS 1um SHEEN
Slick Thickness (mm.)
24
21
18
15
12
9
6
3
0
Oil
Emulsion
0
1
2
3
Total Run Time (Days)
ALL THICK OIL GONE


EXERCISE SPILL AT 10 m/s
Emulsion Water Content (%)
100
75
50
25
0
Density (kg/cu.m.)
1025
950
875
800
Viscosity (mPas.)
1000000
100000
10000
1000
100
10
1
0
1
2
3
Total Run Time (Days)

The day before the trials a helicopter flight over the test area was undertaken; a few kittiwakes and large gulls, 2 fulmars and 2–3 gannets were observed flying near the site. No birds were seen on the water.

During the trials only flying birds were seen; scattered fulmars, greater shearwaters, black–backed and herring gulls, gannets and a petrel. All were observed moving through the area; none were attracted to ships or oil and none were on the water.

The day after the trials only two birds, probably a fulmar and a gannet were observed in the vicinity of the slick; no birds were observed in the water, in the slick or oiled.

It is concluded that the slick had no impact on seabirds in the area.

During the two week period following the trials there were no reports of shoreline or fishing gear oiling (G. Pelly personal communication) resulting from the trials.

In summary, the tests had no (or very little) impact on the local environment.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

1. Although the objectives of the skimmer tests were met, due to delays, deteriorating weather conditions and the addition of Elastol to the slick between skimmer tests (in order to improve recovery rates), it was not possible to quantitatively compare the capability of all the skimmers to recover waxy crude oil spills in seas representative of Grand Banks conditions. The Framo ACW–400 skimmer had an average fluid recovery rate of 39 m^3/hr (170 gal/min) with an oil recovery efficiency of 35% in untreated emulsion. Operation of the Heavy Oil Skimmer in the slick prior to Elastol addition resulted in no measurable recovery. The Heavy Oil Skimmer, during one 6 minute test, recovered Elastol–treated emulsion at an average rate of 11 m^3/hr (50 gal/min) with an oil recovery efficiency of 35%. The GT–185 skimmer recovered Elastol–treated emulsion at an average rate of 19 m^3/hr (85 gal/min) with an oil recovery efficiency of 46%. Qualitatively, the skimmers that operate on the oleophilic principle were ineffective in the untreated waxy oil. Elastol addition improved the recovery rate of the Heavy Oil Skimmer but ~~likely~~ may have detracted from the performance of the GT–185.

2. Both the RO–BOOM and the Vikoma Ocean Pack will contain waxy oil spills in seas representative of Grand Banks conditions up to sea state 3–4 and at relative currents less than 0.5 m/s. The Vikoma Ocean Pack boom was deployed and recovered faster and more easily than the RO–BOOM. The RO–BOOM was prone to splash–over of oil at the junction between flotation chambers; the Vikoma boom was prone to oil losses through dispersion by small breaking waves created at the junction of the air and water chambers. Both booms were judged to be equal in terms of sea–keeping and oil retention capabilities.

3. The sea and weather conditions prevalent at the site during the morning and early afternoon (sea state 3–4; winds 15 to 18 knots) represent the upper limit of stationary containment operations oriented into the wind. By operating in a downwind mode to reduce relative boom/water velocities and skimming in the lee of a vessel, recovery operations were possible in sea state 4 with winds in the 10 m/s (20 knot) range.
Unless the towing vessels are able to manoeuvre without exceeding speeds of 0.5 m/s (1 knot), major losses of contained oil will occur.

5.2 RECOMMENDATIONS

1. Further testing of the skimmers under controlled conditions with waxy, viscous oils is recommended to further assess their capabilities.

2. The use of Elastol, and its effects on recovery operations should be quantified under controlled conditions.

6.0 REFERENCES

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APPENDIX 1

TEST PROTOCOL

TEST PROTOCOL

FOR

OFFSHORE BOOM TRIALS

MAY, 1987

by

S.L. ROSS ENVIRONMENTAL RESEARCH LIMITED
OTTAWA, CANADA

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 OBJECTIVE

The objective of these trials is twofold: first, to determine whether or not the Canadian Coast Guard (CCG) equipment stockpiled in St. John's is suitable for responding to spills of waxy oils on the Grand Banks, and second, verify a protocol for determining the ability of offshore booms to hold oil without having to spill oil (the protocol is the product of several years of joint effort by the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) consortium).

1.2 GOALS

More specifically, the goals of this study are to document and quantify:

1) the sea-keeping and waxy oil retention capabilities of the CCG St. John's Vikoma Ocean Pack and CCG Mulgrave Ro-Boom in seas representative of Grand Banks conditions;
2) the waxy oil recovery capabilities of the CCG St. John's Framo ACW-400 skimmer and the experimental Heavy Oil Skimmer (HOS) in seas representative of Grand Banks conditions; and
3) the sea-keeping and oil retention capabilities of a specially instrumented offshore oil boom in seas representative of offshore conditions.

1.3 TARGETS

The tests are proposed for one day in the time period of September 1 to October 31, 1987 off St. John's, with the week of September 21 as the target.

2.0 GENERAL INFORMATION

2.1 THE OIL

Up to 80 m^3 of a viscous crude oil, with properties similar to those of waxy Grand Bank's crude oils, is proposed for the tests. Sufficient volumes of oils from exploration activities on the Grand Banks do not exist.

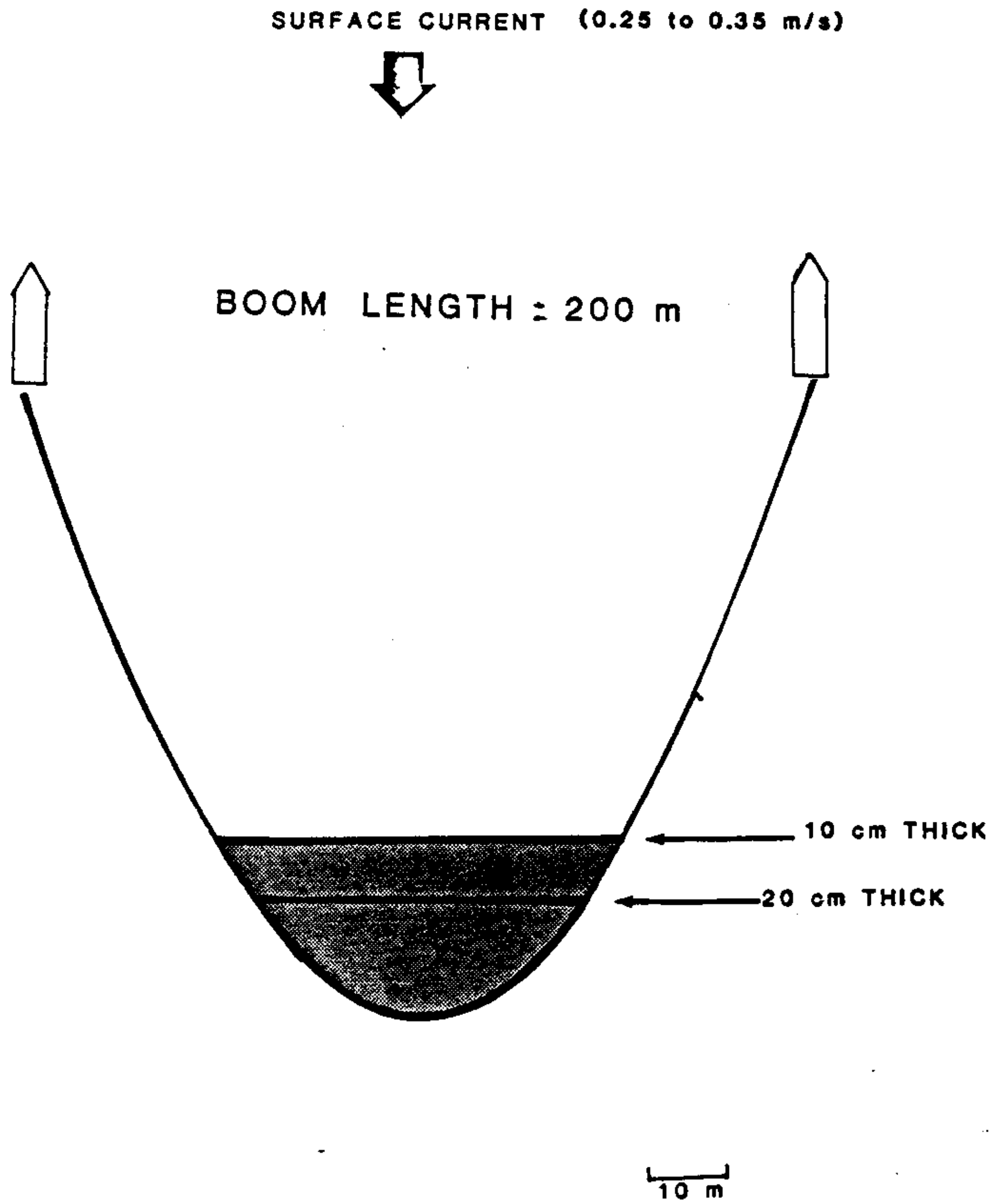
2.1.1 Oil Volume

Based on experience with other such tests (Nordvik 1986 pers. comm.; Griffiths 1986 pers. comm.), approximately 80 m^3 will be needed to develop slick thicknesses in the boom pocket approximating full scale conditions. Figure 1 shows the size of an 80 m^3 slick in relation to a 200 m length of boom held in a catenary.

2.1.2 Oil Properties

Waxy crude oils from exploration activities on the Grand Banks are not available in sufficient quantities for the proposed tests. As such, it is necessary to substitute an oil produced in Canada, doped with wax or Bunker C to produce properties similar to those of waxy oils. The properties of Alberta Sweet Mixed Blend (ASMB) crude oil are compared to those of three waxy Grand Banks crudes in Table 1. The primary difference between ASMB and the waxy crudes is pour point. When weathered for ten hours as a 10 cm thick slick at 15 ^{o}C the pour point of ASMB rises to $0^{o}C$. A small percentage of wax will be added to the ASMB crude oil to raise its pour point when fresh to the 0^{o} - $5^{o}C$ range (so it can be easily released) and raise its pour point when weathered to the $15^{o}C$ range (so it exhibits typical waxy oil behaviour after release).

FIGURE 1 - RELATIVE SIZE OF AN 80 m3 CONTAINED SLICK



2.2 PROPOSED TEST LOCATION

The proposed test area has been selected in consultation with the Regional Ocean Dumping Advisory Committee (RODAC) based on the following criteria:

* any minor oil losses must drift out to sea (SSW currents and westerly winds)
* at least 100 m water depth
* at least 20 nm offshore
* within 2 to 3 hours sailing from St. John's.

This translates to an area (Figure 2) centered at 47° 40'N, 52° 03'W east of St. John's. An area, rather than a specific site, is suggested to permit flexibility in site selection on the day of the trials and to account for "over the ground" drift during the trials. It should be noted that a dry run (involving no oil) of the test procedures would be conducted near St. John's prior to the actual tests.

The site and the possible time window for the trials (September 1 to October 31, 1987) have been specifically chosen to avoid conducting the trials during the fishing season and to optimize the chances of suitable sea and weather conditions.

2.3 WEATHER AND SEA CONDITIONS

This section contains a general description of the physical environment of the proposed test area. The weather and sea condition constraints on the test may be found in Section 2.5.

FIGURE 2 - LOCATION OF SUGGESTED TEST AREA

2.3.1 Winds

Figure 3 shows wind roses and directional frequency data for the proposed site in fall. In September westerly (SW - NW) winds occur 54% of the time, at speeds less than 16 knots about 60% of the time. In October westerly winds occur about 48% of the time, at speeds less than 16 knots about half the time. Persistance information is given in Section 2.5-Operating Constraints.

2.3.2 Currents

Residual currents in the proposed area set to the southwest at speeds on the order of 15 cm/s (0.3 knots). The greatest combined current (wind plus tide plus residual) reported is slightly in excess of 1 knot.

2.3.3 Waves

Waves in the proposed study area exceed 2 m 50% of the time in fall. Figure 4 shows the occurrence of favourable waves for containment and recovery (i.e., waves less than 1 m in height and between 1 m and 2 m in height with periods longer than 6 s) for the Grand Banks. Since waves on the Grand Banks tend to be slightly higher than those closer to shore, the graph is conservative. Favourable waves can be expected about 20 to 50% of the time in fall; the highest probabilities for favourable waves occur in early fall.

2.3.4 Temperatures

In fall the average air temperature is in the 10°C range; the sea temperature is in the 5°C range.

FIGURE 3 FALL WINDS

PERCENTAGE FREQUENCY BY DIRECTION

September

	St. John's	SSMO4
N	9.5	11.7
NE	8.5	7.0
E	4.0	5.7
SE	5.5	6.1
S	9.5	13.5
SW	24.0	25.2
W	28.0	18.1
NW	9.0	10.7
Calm	2.0	1.9

October

	St. John's	SSMO4
N	11.0	10.8
NE	5.0	5.7
E	3.5	4.7
SE	5.5	6.2
S	11.5	13.1
SW	21.5	20.8
W	26.5	23.1
NW	13.5	14.3
Calm	2.0	1.4

WIND ROSES
SSMO AREA 4
SOUTHEAST NEWFOUNDLAND

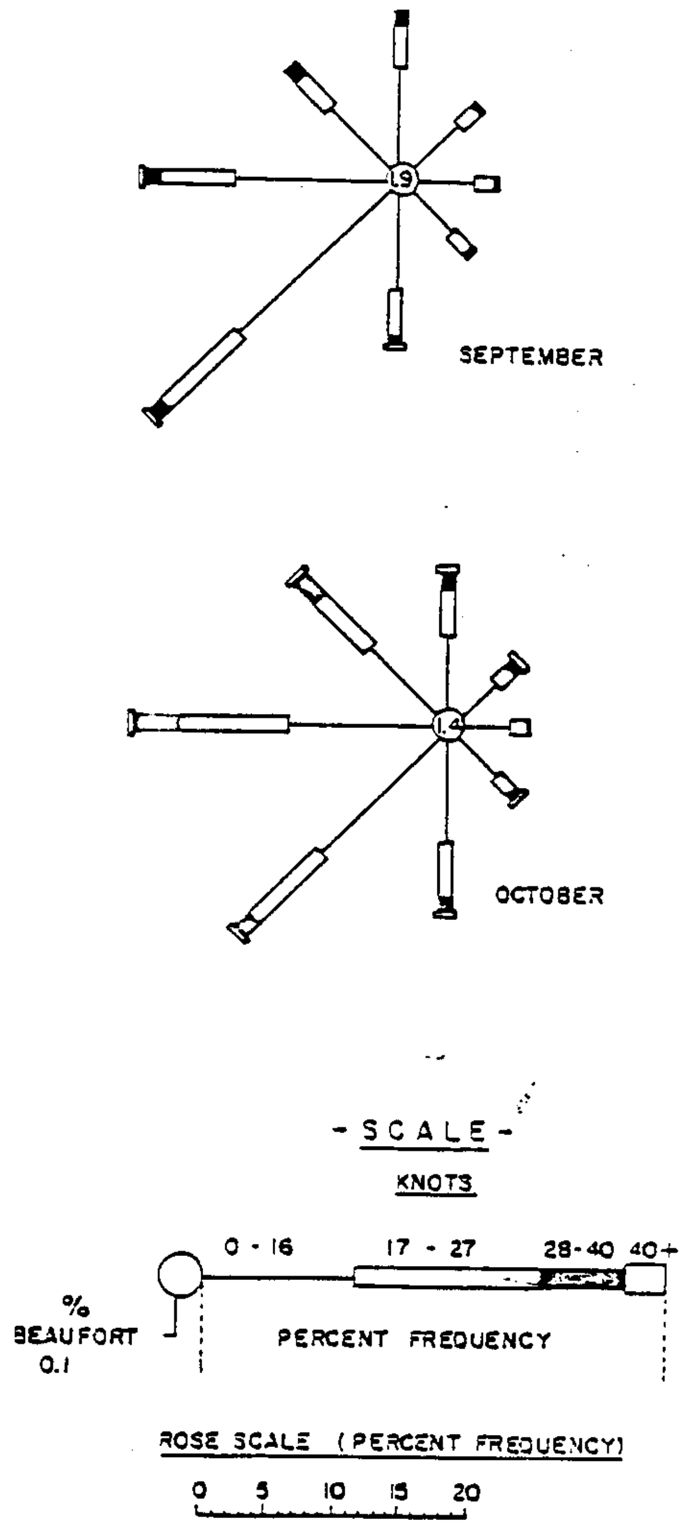
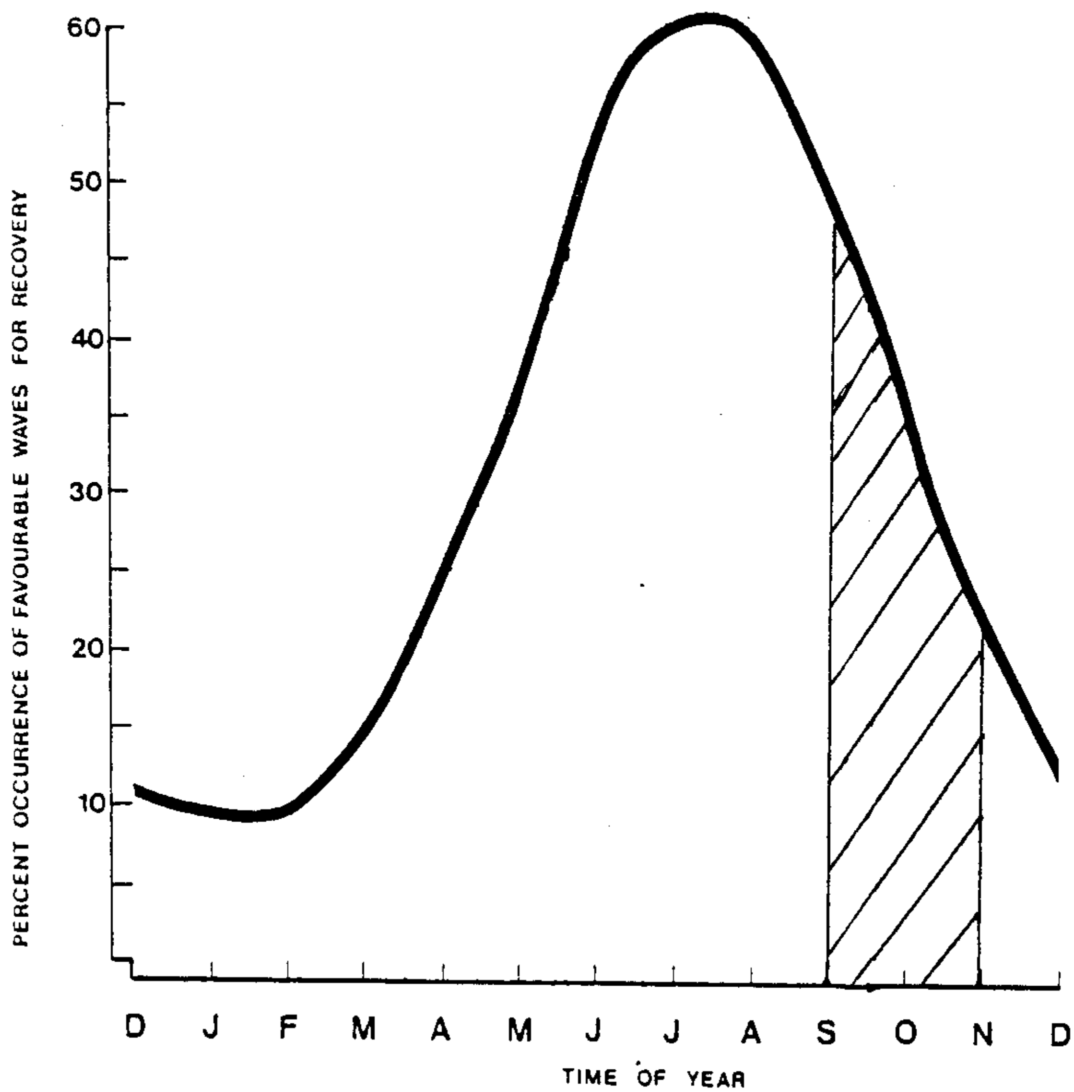


FIGURE 4

OCCURRENCE OF FAVOURABLE WAVES FOR CONTAINMENT/RECOVERY



2.3.5 Visibility

Figure 5 shows visibility statistics for the region of the proposed site. In September, visibility is less than 2 nm about 18% of the time; in October this decreases to about 10% of the time. At St. John's, in September, an average of 7 days are foggy; in October an average of 8 days are foggy.

2.3.6 Precipitation

Figure 6 shows the occurrence and type of precipitation in the area of the proposed test site. In fall there is no significant precipitation 70% of the time.

2.4 PROJECT TEAM

This project is being supported by the Canadian Coast Guard, Environment Canada, the U.S. Environmental Protection Agency, the U.S. Minerals Management Service and the U.S. Coast Guard. The project is directed by a Steering Committee comprised of nine members as shown on Figure 7. Mason and Hanger, operators of the EPA OHMSETT facility will undertake all oil discharge, boom and skimmer measurements, S.L. Ross Environmental Research Limited, D.F. Dickins Associates Limited and Seakem Oceanography will be responsible for project co-ordination and planning, oceanographic and meteorological measurements and assessment of the Coast Guard booms. The Canadian Coast Guard will co-ordinate logistics, vessels and manpower.

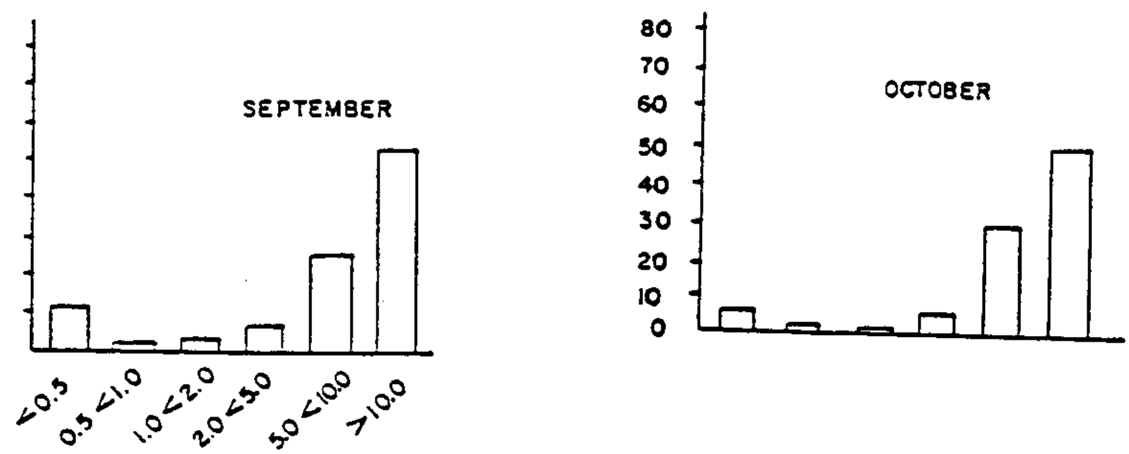


FIGURE 5 VISIBILITY (nautical miles)
SSMO AREA 4
SOUTHEAST NEWFOUNDLAND

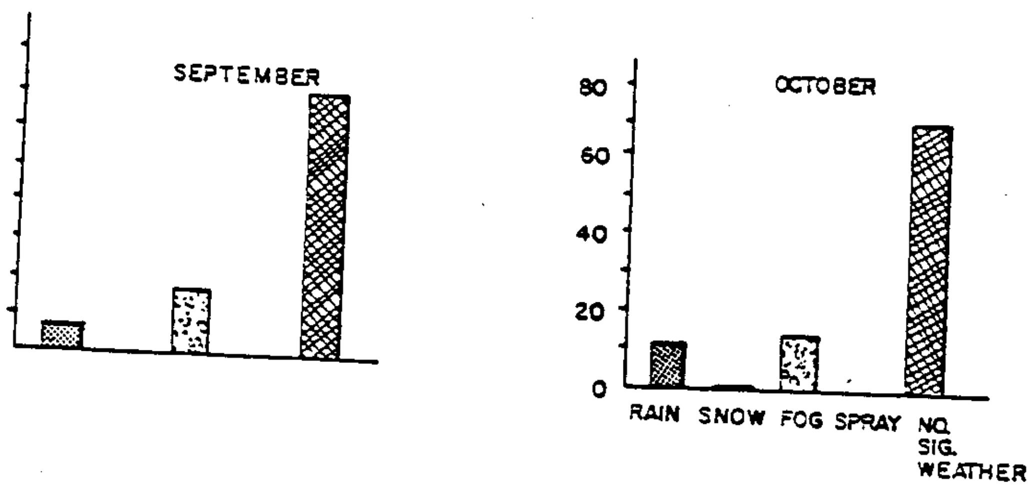


FIGURE 6 PRECIPITATION
SOUTHEAST NEWFOUNDLAND
SSMO 4

FIGURE 7

PROJECT TEAM ORGANIZATION

STEERING COMMITTEE

- H. Whittaker, C&P-EETD
- E. Gauthier, CCG-HQ
- W.Ryan, CCG-NFLD
- R. Griffiths, US EPA
- J. Sinclair, USCG-R&D
- R. Percy, C&P-ATL
- E. Tennyson, US MMS
- H. Bain DFO-NFLD
- P. Devenis CPA OOA

PROJECT MANAGER - H. Whittaker, C&P-EETD

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et al.

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K. Corradino
J. Nash
R. Dickson
D. Knapp
S. Izzo
N. Norrell
J. Cocherell

PROJECT CO-ORDINATION AND CCG BOOM ASSESSMENT

S.L. Ross Environmental Research Limited
I. Buist
S. Potter

METEOROLOGY

D.F. Dickins Assoc.
D. Dickins

OCEANOGRAPHY

Seakem Oceanography
B. Humphrey
N. Hill

HELICOPTER

CCG

AERIAL PHOTOGRAPHY

Aeromap
H. Ripley

2.5 OPERATING CONSTRAINTS

The following defines the weather and sea state "window" necessary for commencement of the tests on a particular day:

* wind from 180-330° with speeds less than 20 knots (10 m/s) for 12 hrs during daylight
* visibility greater than 3 km
* ceiling at least 150 m (preferably greater than 500 m)
* wave height between 1 and 2 m, highest 1/3 of waves
* westerly winds predicted to last for at least 36 hr
* no precipitation

Taking into account the first three criteria (wind, visibility and ceiling) an investigation of the historical frequency of occurrence of the weather window was undertaken by AES. In August there were an average of 4.4 occurrences per year, in September there were an average of 3.9 occurrences per year and in October an average of 4.1 per year. Factoring in sea state, precipitation and VFR flying conditions would reduce these numbers to an unknown extent. Westerly winds for more than 36 hrs occurred about 5 times per month; westerly wind for more than 48 hrs occurred about 3 times per month.

3.0 TEST PLAN

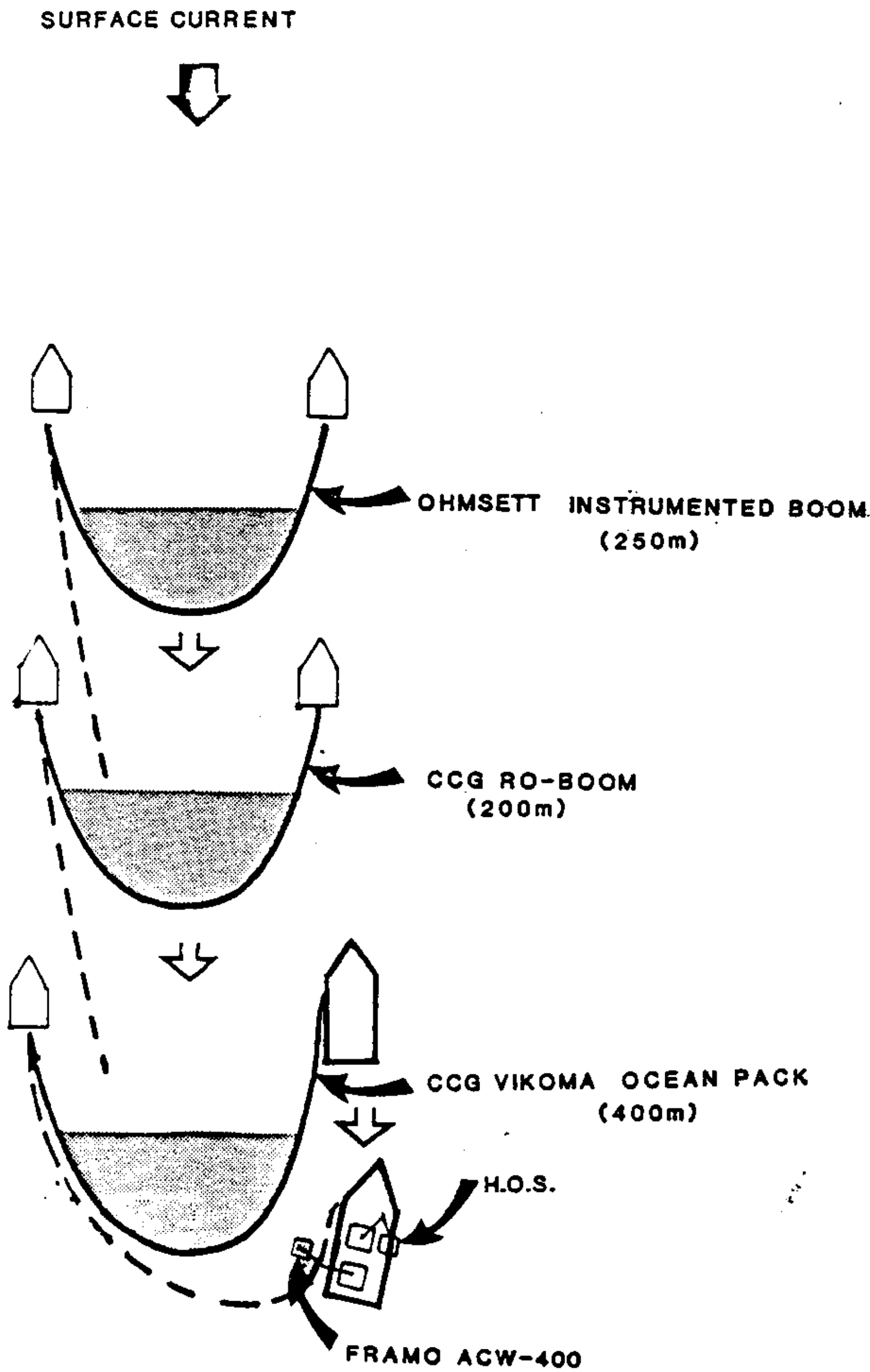
3.1 GENERAL

The general experimental plan is as follows. The 250 m OHMSETT instrumented boom will be deployed first and monitored for 1 h without oil. Once the next boom is set (see Figure 8) and the oil has been discharged into the OHMSETT instrumented boom, readings will be taken for 1 hour in a relative current of about 0.25 m/s (1/2 knot). After this the two boats will speed up until significant entrainment losses occur (at about 0.5 m/s = 1 knot). The lost oil will be collected by the 200 m Ro-Boom (from CCG Mulgrave) being towed behind. After this, one tow boat on the OHMSETT instrumented boom will drop back into the mouth of the Ro-Boom and let go of its end of the instrumented boom thus allowing the oil to drift back into the Ro-boom. The CCG St. John's Vikoma Ocean Pack boom (400 m) will be deployed behind the Ro-Boom to collect any escaping oil. The same test procedure used for the OHMSETT instrumented boom will be repeated for the Ro-Boom.

Once the oil is in the Vikoma Ocean Pack boom it will be observed for 1 hour (no "testing to first oil loss" will be conducted) after which the skimmer tests will commence. A Vikoma Sea Pack boom will be on-site in case of any problems with the Vikoma Ocean Pack boom.

The skimmer testing will involve 20 minutes skimming with the Framo ACW-400 from the side of a supply boat holding the short leg of the Vikoma Ocean Pack boom in a "J" configuration followed by 20 minutes skimming with the experimental Coast Guard Heavy Oil Skimmer (HOS). All the remaining oil will then be recovered by the skimmer with the better performance. The recovered oil will be pumped into two 22 m^3 (5,000 gal) deck tanks and from there back into the dumb barge. There will be sufficient tankage available to recover all the oil, including volume increases due to emulsification.A steam siphon will be inserted in the hose between the skimmer and the deck tanks to break any emulsions.

FIGURE 8 SCHEMATIC OF TEST PLAN



3.2 PRE SPILL MONITORING AND TEST INITIATION

About three weeks prior to the chosen test week, A.E.S. long-range weather forecasts will be obtained for the general test site.On the Monday, weather permitting, a dry-run will be conducted and a test day and location will be selected based on A.E.S. short-range weather and sea state forecasts. An overflight of the test site will take place on the afternoon prior to the chosen test day to check the area for fishing activity and birds. A wave rider buoy with radio telemetry will be placed at the test site after the dry run to allow the waves to be monitored prior to the test day.

3.3 OIL DISCHARGE

It is by no means certain that the entire 80 m^3 of oil will be discharged. The oil will be pumped at a rate of 2 to 4 m^3/min, from a small barge positioned in the mouth of the OHMSETT boom. During this operation a helicopter will hover above the boom to monitor the size of the slick and any oil losses. Should the slick fill 75% of the boom area or significant oil losses occur the oil discharge will be stopped and any remaining oil left in the barge.

3.4 BOOM MEASUREMENTS

Data from differential pressure transmitters and strain links on the instrumented OHMSETT boom will be collected and stored on a mini-computer on-site. Visual observations, photography and video, from both boats and the helicopter, will be used to document the sea-keeping and oil retention characteristics of all three booms. Oil loss rates will be estimated visually. Relative tow speeds will be measured by timing small drifters over a known distance. Tow boat separation heading and orientation will be recorded intermittently. Draft data sheets are given in Appendix I.

3.5 SKIMMER MEASUREMENTS

The measurements to evaluate skimmer performance will include recovery rate (determined by both an in-line flowmeter and tank soundings), emulsion and free-water content (from periodic samples), recovered product physical properties (density, viscosity, etc.) and total volume recovered (by measuring the volume in storage). In addition, visual, video and photographic observations will be used to evaluate qualitative aspects of skimmer performance such as sea keeping, oil entrainment etc. Draft data sheets are given in Appendix I. A steam siphon will be used to break any emulsions; its operating parameters and efficiency will be monitored.

3.6 METEOROLOGICAL MEASUREMENTS

Wind speed and direction and air temperature will be monitored throughout the test day using a weather station mounted on the mast of one of the large vessels.

3.7 OCEANOGRAPHIC MEASUREMENTS

Wave height and frequency data from a wave rider buoy moored at the site will be recorded continuously by a remote computer on one of the large vessels. Surface drift velocities will be determined periodically using drifters in conjunction with aerial video recording. Position fixes and "over the ground" drift will be determined by LORAN-C.

3.8 OTHER

A Polaroid camera attachment will be mounted on one of the search radars aboard a large vessel to document whether or not such a radar can detect oil slicks when the sea clutter suppression is turned down.

4.0 LOGISTICS

4.1 VESSELS

The following CCG vessels will be used for the experiment. The tasks for each are also delineated. Equipment to be carried aboard each is listed in Section 5.0.

CCGS Jackman (or Grenfell)

- converted supply boat
- L.O.A. = 56.1 m
- carry, deploy and retrieve Ro-Boom
- carry, deploy, hold and retrieve Vikoma Ocean Pack boom
- carry and deploy wave rider buoy
- oceanography and meteorology
- carry spare generator for Vikoma Ocean Pack

CCGS Sir Humphrey Gilbert

- carry, deploy and retrieve CG 208, Boston Whaler and FRC
- carry helicopter
- carry backup Vikoma Sea Pack
- recover OHMSETT boom
- recover waverider
- radar and positioning watch
- search radar oil detection tests
- observer/VIP/press platform

CG 206

- converted Cape Islander
- L.O.A. = 12.7 m
- twin 315 hp inboard diesel
- hold one end of OHMSETT boom
- conduct OHMSETT data collection
- tow OHMSETT boom to CCGS Sir Humphrey Gilbert

CG 208

- seatruck
- L.O.A. - 13 m
- twin 215 hp inboard diesel
- carry, deploy and hold OHMSETT boom
- assist with data collection
- wash OHMSETT boom with fire hose

CG 212

- converted aluminum hull workboat
- L.O.A. - 13.6 m
- twin 315 hp inboard diesel
- pull Ro-Boom from stern of CCGS Jackman
- wash Ro-Boom with fire pump
- standby to pull out Vikoma Sea Pack if required
- wash Vikoma Ocean Pack boom

CG 214

- converted aluminum hull workboat
- L.O.A. = 13.6 m
- twin 315 hp inboard diesel;
- position barge for oil release
- take Ro-Boom from CCGS Jackman and position between OHMSETT boom and Vikoma Ocean Pack
- return Ro-Boom to CCGS Jackman

In addition, one or two smaller boats (Boston Whaler and FRC) will be used for close observation of boom behaviour.

As well as the above CCG vessels, a dynamically positioned supply boat is required to undertake the following tasks:

- tow barge to and from site

- hold one end of Vikoma Ocean Pack boom
- carry and operate the Framo and H.O.S. skimmers
- carry two 5,000 gallon tanks and hoses for recovered oil storage
- pump recovered oil to dumb barge and tow barge back
- command centre
- steam siphon tests
- deploy Orion buoy after skimmer tests

4.2 HELICOPTER

A helicopter, capable of flying offshore, is required for the following tasks,

- direct operations
- aerial photography and video
- monitor oil discharge

This helicopter will be based on the CCGS Sir Humphrey Gilbert. A larger helicopter will be used for pre and post spill site monitoring, including tracking an Orion buoy.

4.3 TRANSPORTATION

Transportation to, from and in St. John's is each individual's responsibility.

4.4 COMMUNICATIONS

Good communications is the key to the success of the experiment. Since the majority of the vessels will be CCG owned, the CCG oil spill channel (81A) will be used for all vessel related communications. It may be necessary to supply a suitable radio to the chartered supply boat since

81A is a restricted channel. Helicopter/ship communications will be on channel 19A. The OHMSETT team will use hand-held radios with frequencies of 165.5875 or 164.450 MHZ. CCGS Sir Humphrey Gilbert will monitor channel 11 and CCGS Jackman will monitor channel 16.

In order to prevent confusion on the command ship and helicopter, radio traffic should be kept to a minimum. All radio communications will be tape recorded to provide a record of the day's events.

4.5 SAFETY

Safety during the dry run and test is paramount. All personnel at the test site must wear floater suits or jackets. A safety briefing will be held in St. John's prior to the dry run. The ship's captain or boat operator has ultimate authority over surface operations; the pilot has ultimate authority over airborne operations.

4.6 SHIPPING AND STORAGE

All materials and equipment for the experiment that cannot be hand carried must be received in St. John's the week prior to the tests. The shipping address is

Mr. W. Ryan, BMG
Canadian Coast Guard
Newfoundland Region
Canadian Coast Guard Emergencies
Bldg. 204, Pleasantville
St. John's, Newfoundland
Canada

Attn: OFFSHORE BOOM TRIALS
Telephone: (709) 772-5171
Telex: 016-4530 (a/b CCGTC SNF)

For mail, the address is

P.O. Box 1300
St. John's, Newfoundland
A1C 6H8

Notification of each shipment, including number of pieces, general description, carrier, waybill number(s), shipper, shipping date and estimated arrival date in St. John's should be sent to Ian Buist of S.L. Ross at:

Telephone: (613) 232-1564

Telex: 063-666 (a/b CNCP EOS TOR)

after the answerback is received the first line of your message must be .TO 21:XRE001 with the period in the first column

The shipping information will be telexed to St. John's for confirmation of receipt and shipping damage reports.

5.0 EQUIPMENT LIST

(by end use location; supplier noted in brackets)

CCGS Jackman (or Grenfell)

* Vikoma Ocean Pack and spare generator
* Ro-Boom and reel pack (CCG Mulgrave)
* wave rider buoy (Seakem)
* wave data receiver/computer (Seakem)
* met. station (DFD)
* tape recorder/video (SLR)
* 2 bales sorbent pads (CCG)
* 2 open top drums (CCG)
* surface drifters (DFD)

CCGS Sir Humphrey Gilbert

* CG 208, Boston Whaler and FRC (CCG)
* Vikoma Sea Pack (CCG)
* helicopter and fuel (CCG)
* Polaroid camera and mount (SLR)
* tarp to place recovered OHMSETT boom on (CCG)
* 2 bales sorbent pads (CCG)
* 2 open top drums (CCG)

CG 206

* data collection computer (OHMSETT)
* surface drifters (OHMSETT)

CG 208

* instrumented boom (OHMSETT)
* fire pump and hose (CCG)
* surface drifters (OHMSETT)

CG 212

* fire pump/hose (CCG)
* surface drifters (DFD)

CG 214

* surface drifters (DFD)
* TK 4 pumps for oil release (CCG)

Other supply boat

* barge (CCG)
* Framo ACW-400 (CCG)
* Heavy Oil Skimmer (CCG)
* two 5,000 gallon deck tanks (CCG)
* transfer pump & floating hose (CCG)
* steam siphon and steam generator
* skimmer performance measurement equipment (OHMSETT)
* oil sampling equipment (OHMSETT)
* 4 bales sorbent pads (CCG)
* 2 open top drums (CCG)
* marine VHF radio with 81A (CCG)
* surface drifters (CCG)
* floodlights for night operations
* work shacks (CCG)
* one Orion buoy (CCG)

Helicopter

* marine VHF radio with 19A
* 70 mm aerial camera c/w mount (AEROMAP)
* 1/2 inch video system c/w mount (AEROMAP)

St. John's

* storage tank for oil (CCG)
* transfer pump/hoses (CCG)
* heated indoor warehouse/storage (CCG)
* meeting room (CCG)

Dartmouth

* tanker truck/storage for oil (EPS)

6.0 PROJECT SCHEDULE AND TEST DAY SEQUENCE OF EVENTS

6.1 PROJECT SCHEDULE

The project timetable is shown on Figure 9. Triangles indicate starting dates, circles indicate completion dates and decision points. The dry run is tentatively set for Monday, September 21, 1987. All personnel should be in St. John's for a meeting at 1800 h on Sunday September 20.

6.2 TEST DAY SEQUENCE OF EVENTS

The proposed timing of the day's activities is shown on Figure 10. Figure 11 shows a diagram of the various tasks. It should be noted that a dry run, involving only deployment and retrieval of all equipment, will be held two days before the test day.

In fall there are about 10 to 12 hours of daylight. Based on the timing shown on Figure 10, departure from St. John's would be up to 4 hours before sunrise. Departure times will be finalized, based on final test site selection and the dry run results, the day before the test.

FIGURE 9
PROJECT TIMETABLE

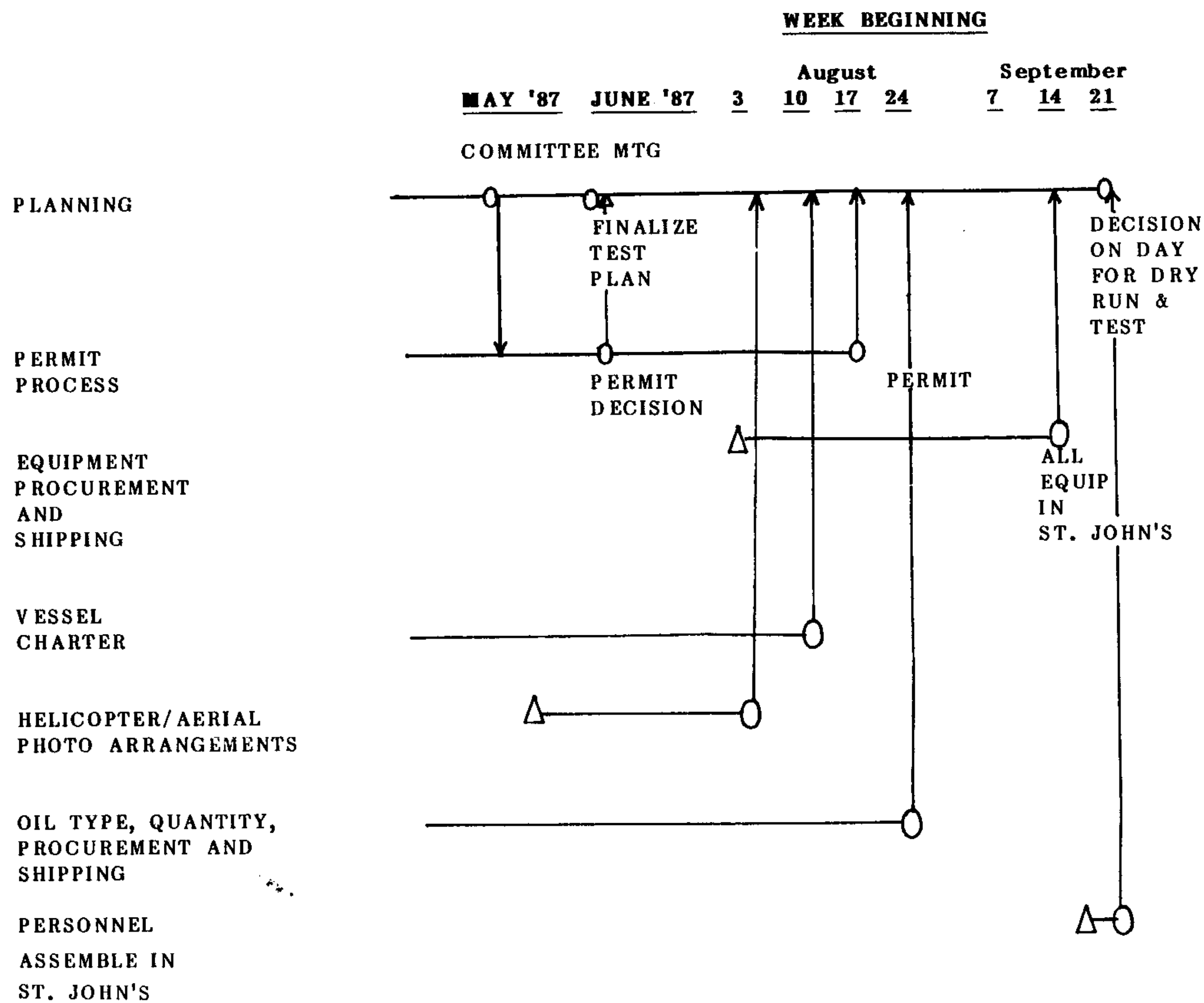
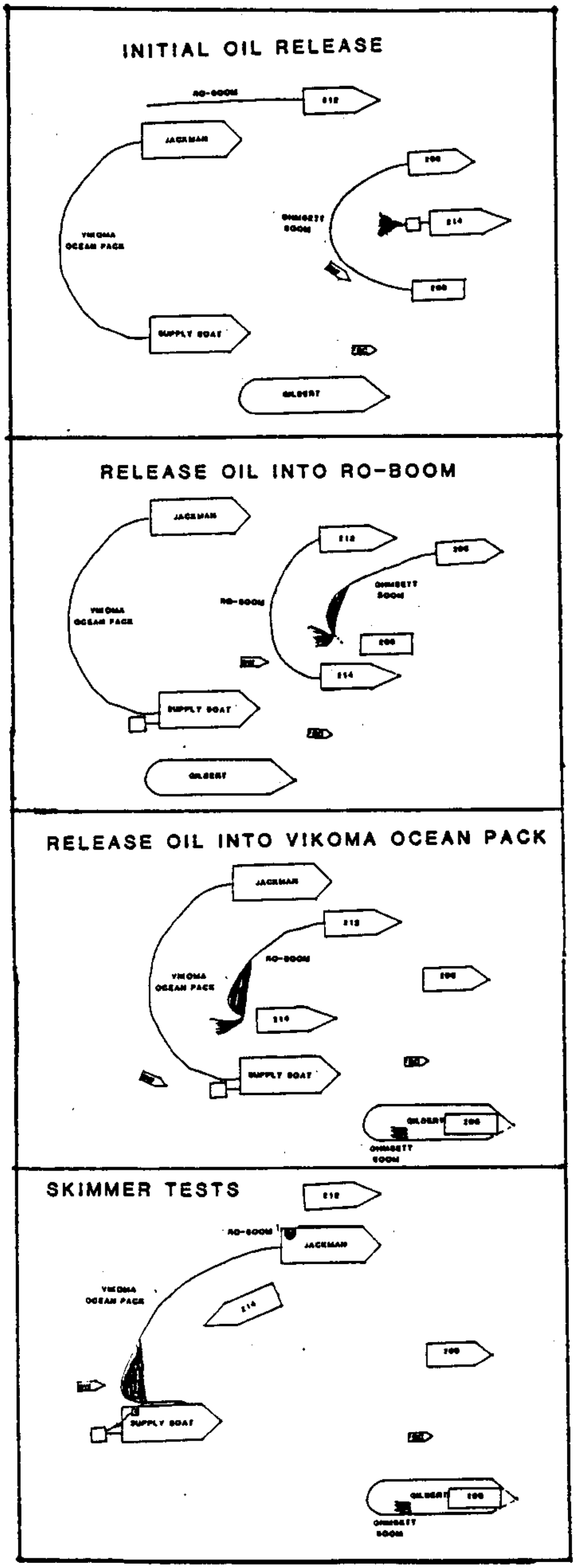


FIGURE 10

TIME (hrs)	SUPPLY BOAT	CCGS JACKMAN	CG 206	CG 208	CG 212	CG 214	CCGS SIR HUMPHREY GILBERT
0	depart for site with barge	depart for site	depart for site	on Gilbert	depart for site	depart for site	depart for site
3	pass barge to CG214	deploy Vikoma Ocean pack behind OHMSETT boom	hold end of OHMSETT boom	deploy OHMSETT boom going astern		take barge from supply boat	deploy CG208 SW and FRC
4	take one end of Vikoma Ocean Pack	deploy Ro-Boom	begin data acquisition	hold OHMSETT boom		position barge in mouth of OHMSETT boom	begin positioning and radar watch
5					take Ro-Boom from CCGS Jackman and stream between OHMSETT boom and Vikoma Ocean Pack	release oil slowly	
6						return barge to CCGS Jackman pick up one end of Ro-Boom & position behind OHMSETT boom	
7			speed up to first loss of oil then slow after oil released tow OHMSETT boom ahead for washing in mouth of Ro-Boom	speed up to first loss of oil then fall back from CG206 release OHMSETT boom in mouth of Ro-Boom wash down OHMSETT boom	bring Ro-Boom close astern of OHMSETT boom	bring Ro-Boom close astern of OHMSETT boom	
8	hold Vikoma behind Ro-Boom	hold Vikoma Ocean Pack behind Ro-Boom		proceed to Gilbert for recovery			recover CG 208
9	bring Vikoma Ocean Pack close astern of Ro-Boom	bring Vikoma Ocean Pack close astern of Ro-Boom	tow OHMSETT boom to Gilbert for recovery		speed up to first loss of oil then slow after oil released hold Ro-Boom for washing in mouth of Vikoma Ocean Pack then tow to CCGS Jackman	speed up to first loss of oil then fall back from CG 212 release end of Ro-Boom in mouth of Vikoma Ocean Pack wash down Ro-Boom stdby	recover OHMSETT boom
10		recover Ro-Boom	stdby				monitor
11	fall back to form "J" commence skimming tests pump oil to barge						
12						wash down Vikoma	
13	deploy Orion buoy	recover Vikoma Ocean Pack					recover SW and FRC recover waverider
14	depart for St. John's	depart for St. John's	depart for St. John's		depart for St. John's	depart for St. John's	depart for St. John's
17	arrive St. John's	arrive St. John's	arrive St. John's		arrive St. John's	arrive St. John's	arrive St. John's

FIGURE 11 - SCHEMATIC OF TEST TASKS



7.0 ENVIRONMENTAL PROTECTION

Every effort will be made to ensure that no oil remains behind at the end of the tests. The proposed site and test timing was suggested by CCG-St. John's to specifically avoid interference with local fisheries and birds, after consultations with local fishermen and regulatory authorities.

7.1 PRE-SPILL SITE RECONNAISSANCE

The afternoon prior to the tests the area will be overflown to ensure that no fishing activity is underway and that no major bird populations are in the area.

7.2 OIL DISCHARGE

The oil would be discharged slowly (2 to 4 m^3/min) by pumping in a controlled manner from individual holds in the dumb barge positioned in the mouth of the OHMSETT boom. The size and control of the slick in the boom pocket will be constantly monitored from the helicopter. Should the slick fill 75% of the boom or begin to leak from the boom the discharge will be stopped and any remaining oil left on the barge.

7.3 BACK-UP BOOMS

At all times during the oil discharge, boom testing and first-loss testing a back-up boom will be positioned behind the test boom to capture and contain any oil losses. The exception to this is the testing of the Vikoma Ocean Pack boom, which will not involve first loss testing and will be conducted at speeds far below that resulting in boom failure, a Vikoma Sea Pack will be on site in case of problems with the Vikoma Ocean Pack.

7.4 BOOM WASHING

After testing of each boom and the release of the contained oil, the boom will be streamed in the mouth of the next boom and washed off with fire hoses. All care will be taken to ensure that the washed off oil drifts back into the next boom's pocket. As the skimming of the oil from the Vikoma Ocean Pack boom progresses, the oil-side of the boom will be hosed off, with the removed oil flushed toward the skimmer for recovery. This procedure will ensure that no oil is released when the Vikoma Ocean Pack boom is recovered. Sorbent pads will be used to wipe off each boom as it is recovered.

7.5 POST-SPILL SITE MONITORING

After the skimming test a radio-trackable Orion spill buoy will be deployed at the test site. The day following the tests a helicopter will be used to locate the test site and ensure that no oil remains.

APPENDIX 2

OCEAN DUMPING PERMIT

Environment Canada / Environnement Canada
Conservation and Protection / Conservation et Protection

Environmental Protection
Conservation and Protection
Environment Canada
3rd Floor, Queen Square
45 Alderney Drive
Dartmouth, N.S.
B2Y 2N6

Your file / Votre référence

Our file / Notre référence

4543-2-02117

September 16, 1987

Mr. Ian Buist
S. L. Ross Environmental
Research Limited
346 Frank Street
Ottawa, Ontario
K2P 0Y1

Dear Mr. Buist:

RE: OCEAN DUMPING CONTROL ACT PERMIT FOR: GRAND BANKS (Offshore Test Spill) #1, St. John's North, Newfoundland

We enclose Ocean Dumping Permit No. 4543-2-02117 to cover the dumping operation you propose to carry out at the above location.

This was published in a regular addition of the Canada Gazette on September 12, 1987 and is valid from September 12, 1987 to November 15, 1987.

The terms and conditions of this permit stipulate that the Permittee shall provide the District Director, Environmental Protection, Newfoundland District, a schedule for the experimental discharge, at least 7 days before the start of this operation. Confirmation or revision of this schedule must be provided at least 24 hours prior to commencement. Also, a report is required within 30 days of completion of the work outlining the actual quantity of material disposed of pursuant to the permit the date(s) on which the activity occurred, quantity recovered, extent of area affected by losses, and any significant deviations from the plan.

Please advise this office when the proposed operation commences and concludes.

Yours truly,

Alan McIver
A/Chairman
RODAC, Atlantic Region

DRA/sfs

cc: RODAC Members
C. Strong
H. Whittaker
W. Ryan
R. Percy
J. Neate
G. Pelly

Canada

ENVIRONMENT CANADA

OCEAN DUMPING CONTROL ACT

Pursuant to the provisions of the Ocean Dumping Control Act, the following permit is approved:

PERMIT NO. 4543-2-02117

Grand Banks (Offshore Test Spill)#1
St. John's North, Newfoundland

1. PERMITTEE

S.L. Ross Environmental Research Limited

2. TYPE OF PERMIT

To release a petroleum based medium for the purpose of testing of oil spill containment booms in open ocean conditions.

3. TERM OF PERMIT

Permit valid from September 5, 1987 to November 15, 1987.

4. LOAD SITE

47°34' N; 052°43'W

5. DUMP SITE

47°40' N 052°03' W, being the point at which oil will be released for the purposes of this expermental program in waters approximately 180m in depth and located 25 nautical miles from land. This location is within the area approved under the terms of this permit for experimentation being defined as that quadrant bounded by positions:

47°48' N; 052°13' W	47°50' N; 052°00' W;
47°28' N; 052°06' W	47°31' N; 051°53' W;

6. EQUIPMENT

Vessels, helicopter and three oil spill containment booms; OHMSETT-Globe boom, RO-BOOM and VIKOMA.

.../2

7. METHOD OF DUMPING

The test oil will be transported to the experiment start site and discharged in a controlled manner from a barge into the mouth of the deployed OHMSETT- Globe boom. During this operation a helicopter will hover over the boom to monitor the size of the slick and any oil losses. Should the slick fill 75% of the boom area or significant oil losses occur the oil discharge will be stopped and any remaining oil left in the barge.

8. TOTAL QUANTITY TO BE DUMPED

Not to exceed 80 m^3 of oil, having approximate physical properties as follows:

Density	856.6 kg/m^3 at o°C
Vapour Pressure	18.6 kPa at 37.8°C
Viscosity	43.7 mPas at 0°C
Pour Point	-8°C (fresh)
	0°C (weathered 10 hrs. at 10°C)

This petroleum product will be modified through the addition of small amounts of wax or bunker "C" to bring its pour point to near that characteristic for Hibernia crude oil.

9. MONITORING REQUIREMENTS AND DUMPING RESTRICTIONS

9.1 The Permittee shall provide the District Director, Conservation and Protection, Environmental Protection, Nfld. District Office, Atlantic Region, with a schedule for the expermintal discharge at least 7 days prior to the start of the expermintal program. Confirmation or revision of this schedule shall be made to this office by hard copy (FAX 709-772-5097) or by phone (709-772-5488) at least 24 hours prior to commencing the experiment.

9.2 A report outlining the following shall be submitted to the District Director, Conservation and Protection, Environmental Protection , NFLD. District, Atlantic Region, within 30 days of the completion of this experiment:

i) quantity of material discharged;
ii) date of discharge;
iii) quantity of oil recovered through cleanup measures;
iv) the extent of area affected by any losses; and
v) any significant deviation from the accepted project plan.

.../3

As well, five copies of a final report describing the experiment and its results shall be provided to the District Director within a period of three months of completion of the experiment.

9.3 Deployment of the test equipment in a manner to reflect the actual experimental protocol using a biodegradable test oil substitute, such as wood chips, must be conducted prior to the actual testing program.

9.4 The experiment shall not be undertaken if it appears that environmental conditions exist which are likely to transport oil to shore or to significant wildlife concentrations in the area.

9.5 No experiment may be undertaken if environmental conditions limit the effective use of aerial surveillance for the purpose of monitoring the progress of operations at the site.

9.6 Aerial reconaissance of the designated experimental area must be undertaken, prior to the release of the test medium, for the purposes of identifing locations of significant wildlife populations within the test sector. A representative from the Conservation & Protection, Canadian Wildlife Service must be in attendance during this overflight.

9.7 The Permittee shall ensure, to the best of his ability and to the satisfaction of the Ocean Dumping Inspector, that at the termination of the experiment, no oil remains in a quantity which could result in significant environmental problems.

9.8 A "Notice to Mariners" shall be issued through the Coast Guard Radio Service 48 hours in advance of the most likely time period for the commencement of testing and continue until the conclusion of the experiment.

9.9 During the pretrial and actual testing phases covered by this permit two Ocean Dumping Control Inspectors must be in attendance, one located in the helicopter being used as the control observation platform and the other located on the operational control vessel.

9.10 All meteorologic services are to be provided through or approved by the Atmospheric Environment Service.

9.11 The Permittee shall provide the Ocean Dumping Inspector with a representative sample of the test oil prior to the test initiation for the purposes of verifying a requirement that the oil have a specific gravity of less that 0.90.

9.12 Upon completion of the testing program the Permittee will supply the Ocean Dumping Inspector with a sample of the recovered oil to be used as a reference material to verify or disclaim reports of damage to propert resulting from losses of oil that may occur during the testing procedure.

9.13 The Permittee, as per the written undertaking in the name of S.L. Ross & Associates, assumes a commitment to clean, repair or replace any fishing gear and undertake to clean any shorelines reported and confirmed to have been oiled through this testing program during a two week period following its completion.

9.14 In the event that on the day of actual experimentation that delays or equipment failure result in a situation in which the oil used in this experimental program is unable to be recovered that day in quantities sufficient to meet the terms of item 9.7 of this permit the Permittee shall either:

i) detail sufficient vessels and containment boom to the site and contain the discharged oil until such time as the oil recovery is accomplished;

or,

ii) engage in alternative activities to achieve these objectives in whole or part, with the approval of the Ocean Dumping Inspector and in consultation with C&P Environmental Protection.

9.15 The Permittee shall undertake at least one overflight of the test area 24 hours following the completion of the experimentation for the purpose of determining the size and locaion of any remaining oil slicks.

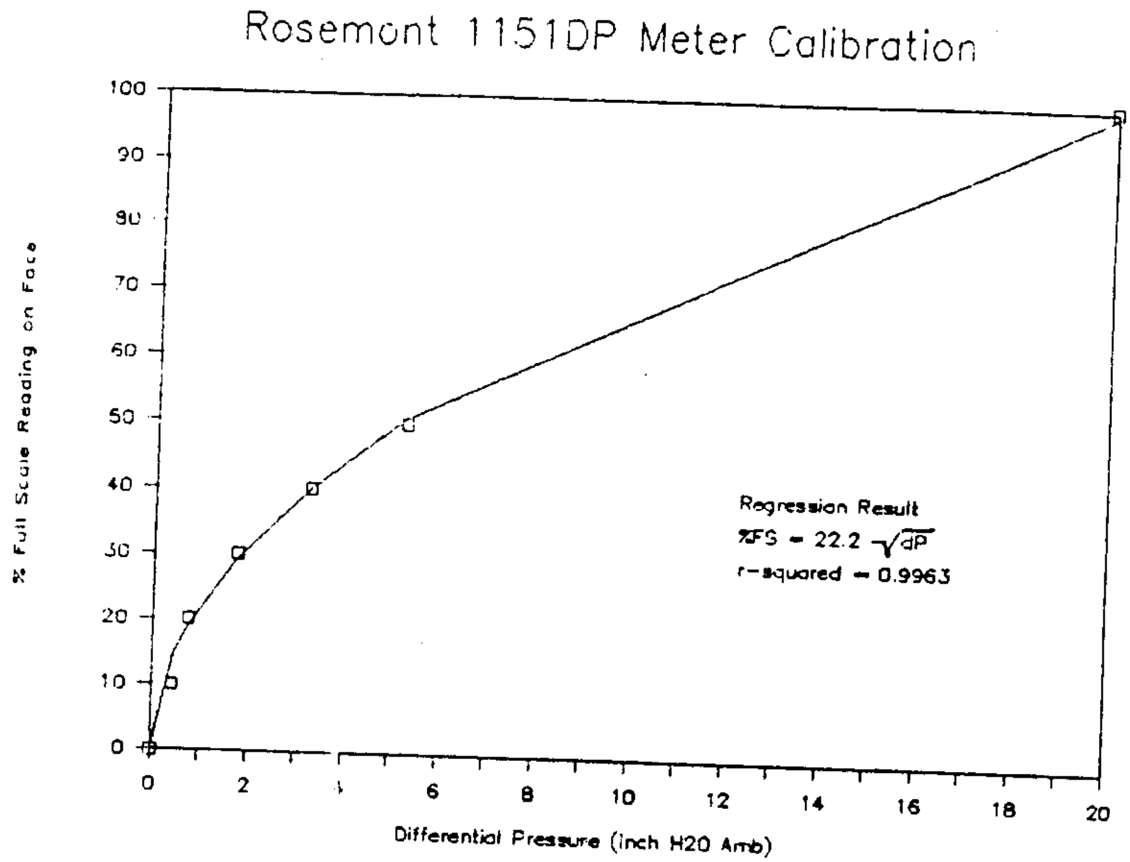
E. J. NORRENA

Regional Director
Environmental Protection
Conservation and Protection
Environment Canada
Atlantic Region
For Minister of the Environment

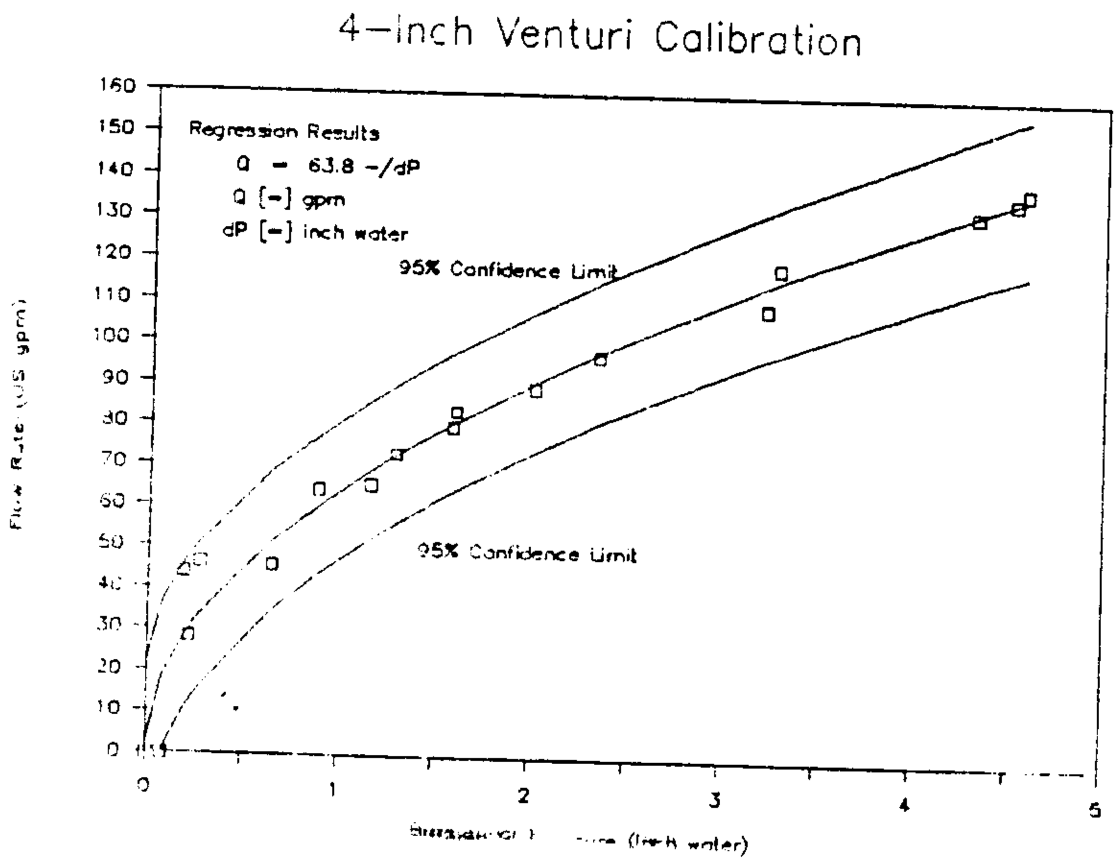
APPENDIX 3

OHMSETT EQUIPMENT CALIBRATION

Exhibit 46. (a) Calibration of a Rosemount Differential Pressure Gauge, and (b) Venturi Tube.



(a)



(b)

Exhibit 47. Demonstrated Linearity of Venturi Flow Meter at 20-inch Full Scale Deflection.

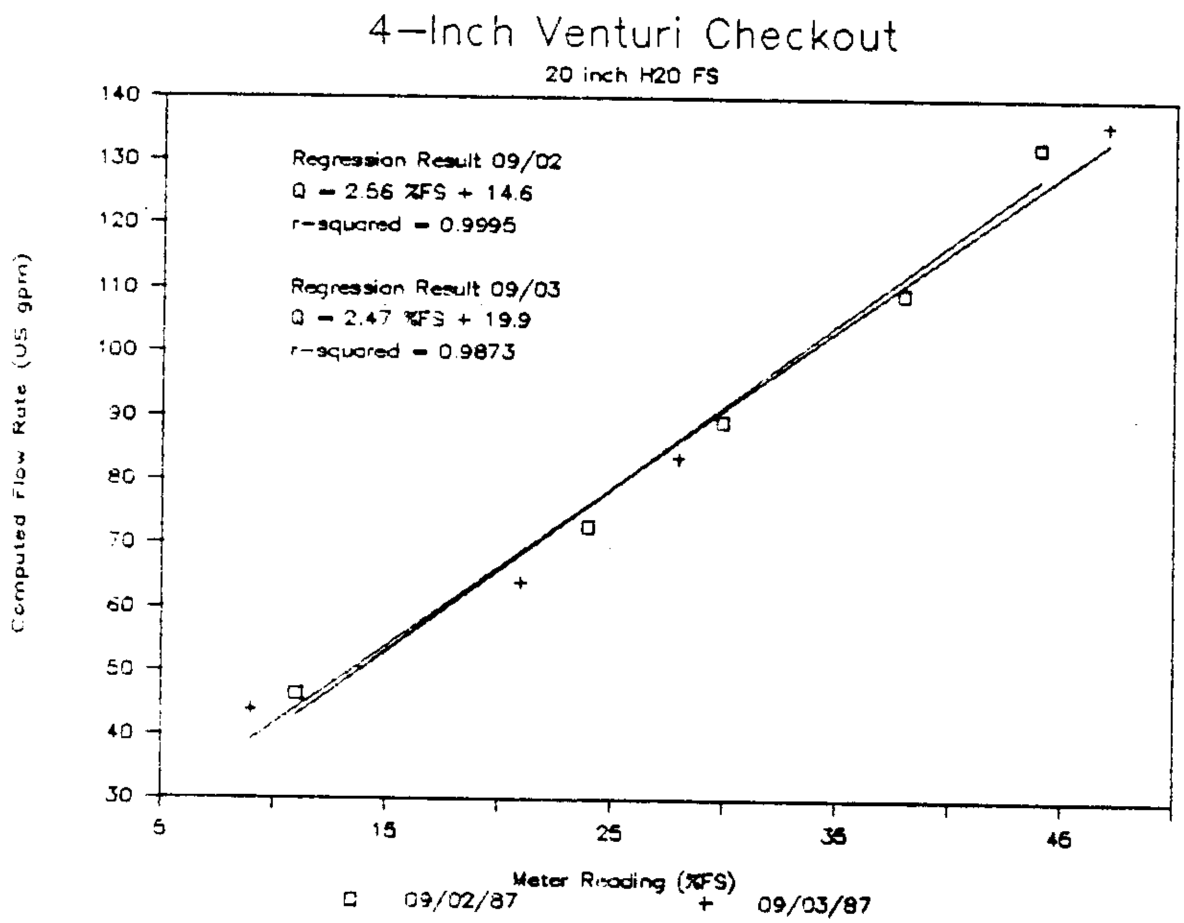


Exhibit 48. Linearity and 98% Confidence Limits for Venturi Flow Meter, 10-inch (H_2O Full Scale Deflection.

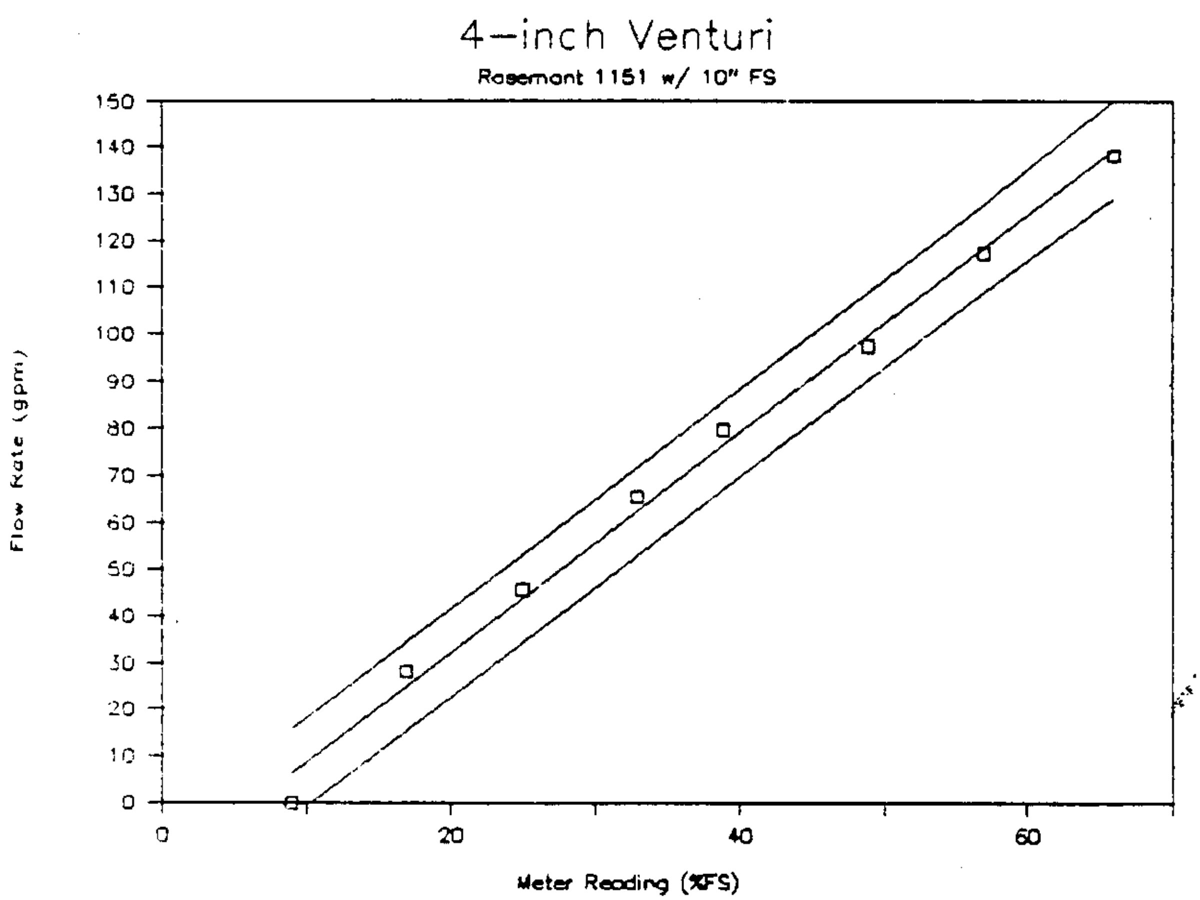
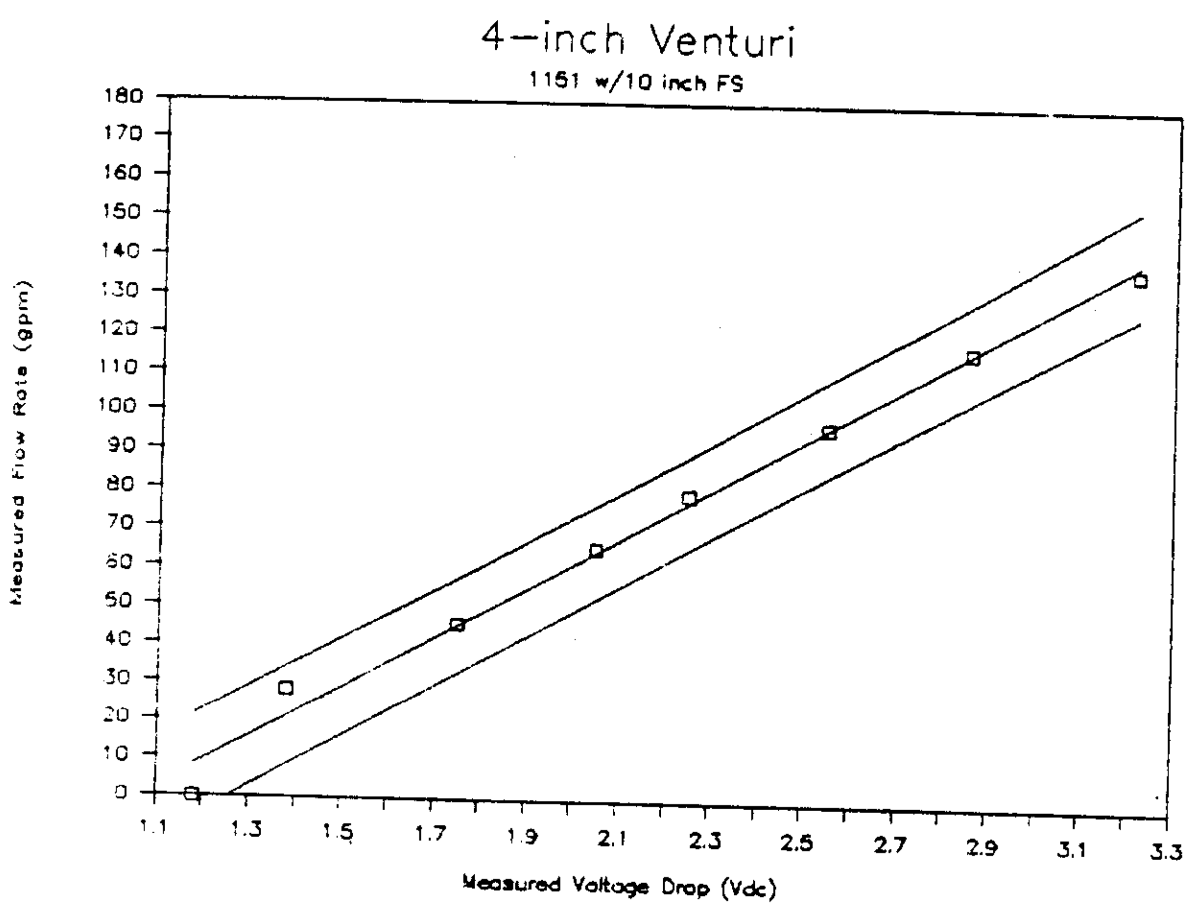


Exhibit 49. Linearity of Voltage Output of Venturi Flow Meter.



APPENDIX 4

ENVIRONMENTAL DATA

WEATHER LOG
OFFSHORE BOOM TRIALS

Date September 24, 1987

Time	Wind Speed	Wind Direction	Ship Heading	Ship Drift	Air Temp	Water Temp	Comments
Local	kt	Rel to Ship		kt	°C	°C	
0710	12-14	075	136		12	12	On site, pre boom
0813	9-12	110	093		12		1/2 Albany out
0830	10-14	115	081				Sea Est. 2.5 m swell
0848	10-14	315	245	SPILLING OIL			plus 0.6 m wind wave
0900	10	350	222		12.5		Albany being man.
0915						12	Vikoma out
0930	11-14	350	221		12.7		Oil in Ro boom
0945	10-12	350	218				Vikoma being man.
1000	11-14	345	221				by Terra Nova Sea
1015	9-115	340	226				1.5 m swell + 0.5m
1030	14-18	337	221		12.7		
1045	12-16	337	221				
1100	12-14	350	207	0.32			Ro dumped @ 1050
1115	14-18	352	209		13.2		
1130	15-17	345	223	0.16			
1145	15	345	222		13.2		Ship sppeded up
1200	16-20	345	221	0.25	13.7		some oil loss
1215	16-19	315	221		13.7		2 m NE swell + 1 m
Ohmset being repositioned							wind wave @ 10-15 m
							wavelength, whitecaps

DF Dickins
Associates Ltd.

WEATHER LOG

OFFSHORE BOOM TRIALS

Date September 24, 1987

Time Local	**Wind Speed** kt	**Wind Direction** Rel to Ship	**Ship Heading**	**Ship Drift** kt	**Air Temp** °C	**Water Temp** °C	
1230	14-17	305	240	0.0 *			* beam on to wind
1245	14-17	265	306				OHMSETT aband.
1300	15-19	250-265	306				reposition VIKOMA
1315	16-19	335	219	1.26			Hdg. into wind with
1325				0.86			thick slick in boom
1330	14-16	025	176				all oil lost
1341				1.72			I. Buist suggests -
1345	14-18	025	173		13.9		chasing oil downwi
1400	10-13	235	320				circling to approach -
1407 -9				1.2 -.3			oil downwind
1417	16	007	186	1.1			dark oil close by
1426				0.7			
1431	14-16	360	193		13.8		oil still in VIKOMA
1442				1.2-1.56			
1445	15-17	025	166				lost most of the oil
							in man. for J
1500	11-14	050	147				1.5 m swell + 0.6-1 m
1518	13-16	135	063				wind wave 10-20 m Leng
1532	11-16	090	105		13.0		start VIKOMA recovery
1545	10-14	090	080		13.3		steaming

DF Dickins
Associates Ltd.

WEATHER LOG

OFFSHORE BOOM TRIALS

Date September 24

Time Local	**Wind Speed** kt	**Wind Direction** Rel to Ship	**Ship Heading**	**Ship Drift** kt	**Air Temp** °C	**Water Temp** °C	
1600	14	206 True	Corrected				Ro boom has 4-5" oil over 25 sections
1615	13-15	210	000		13.5		ship @ 2-3 kt
1630	13-17	035	168				sea est. at 2 m long
1645	13-16	030	174				period sell + 0.6 to
1700	15	020	179				1 m wind wave
1730	15-17	305	263				skimming started
1745	13-16	360	213		14		
1800	15-17	010	204				
1815	15-17	165	051		14.2		
1830	15-17	155	053				
1845	16-21	150	052				
1900	16-20	035	168		13.5		
1915	17-22	050	167				sea est. @ 1.5 m swe
1930	18-22	045	172			12	+ 1 m+ wind wave 15-2
1945	18-23	045	169				m wavelength
2000	15-19	045	169				
2015	15-20	045	169				
2036	18-22	040	168				boom released
END OF	RECORD						

DF Dickins
Associates Ltd.

Environment Canada | Environnement Canada

Atmospheric Environment | Environnement atmosphérique
Scientific Services
P. O. Box 9490
Postal Station B
St. John's, Nfld.
A1A 2Y4

October 19, 1987

Your file Votre référence

Our file · Notre référence
8959-13

Mr. Ian Buist
S.L. Ross Environmental Research Ltd.
346 Frank Street
Ottawa, Ontario
K2P 0Y1

Dear Mr. Buist:

As requested, attached is a brief summary of the St. John's Airport winds for the period 24-27 September 1987.

Mr. F. S. Porter
Scientific Services Meteorologist

Attachment

ST. JOHN'S AIRPORT WINDS

SEPT. 24 - 27, 1987

Sept. 24:

Winds were generally southwesterly. Speeds in the morning were mostly less than 10 knots but, by noon, had increased to 15 to 25 knots.

Sept. 25:

Winds were southwesterly 8 - 15 knots with daytime gusts to 28 knots.

Sept. 26:

Winds were westerly. In the early morning speeds were less than 10 knots, but later in the morning the winds increased. During the afternoon, winds were up to 26 knots with gusts to 37 knots. Winds diminished during the evening.

Sept. 27:

Light south to southwest winds early in the morning increased to 25 - 33 by midday. Near mid-afternoon, winds became westerly 10 - 25 knots.

APPENDIX 5

SKIMMER DATA

Exhibit 54. Telog Data Output for the Framo Skimmer.

SAVED RECORDER STATUS

Type: 2102 42 Range: [illegible] 213. GPM Recorder ID: [illegible]

Approx. time at Recorder: 09/25/87 05:15:07

Time of last Recorder update: 09/20/87 04:21:06

Values being saved: minimums averages maximums

Alarm status: Low alarm @ [illegible] is OFF Upper alarm @ 216. is OFF

Current averaging period: 00:00:03

Amount of time history data recorded: 00:19:18

Storage Capacity: 1600 values records: 00:26:39

Output compressed by a factor of 1

Date	Time	Min	Avg	Max
09/25/87	04:56:16	-53.3	38.9	103.5
09/25/87	04:56:19	-52.8	37.9	124.5
09/25/87	04:56:22	-53.1	28.5	109.1
09/25/87	04:56:25	-51.2	-3.7	74.4
09/25/87	04:56:29	23.5	47.5	82.9
09/25/87	04:56:31	-53.1	25.9	82.9
09/25/87	04:56:34	-51.2	13.7	89.1
09/25/87	04:56:37	-53.3	-20.0	22.1
09/25/87	04:56:40	-53.3	-11.7	48.8
09/25/87	04:56:43	-53.3	18.4	82.1
09/25/87	04:56:46	23.3	59.5	97.9
09/25/87	04:56:49	-45.1	54.1	124.8
09/25/87	04:56:52	-53.3	62.7	141.3
09/25/87	04:56:55	-53.3	-19.7	47.2
09/25/87	04:56:58	-53.1	72.3	135.5
09/25/87	04:57:01	-53.1	93.6	199.2
09/25/87	04:57:04	-53.1	14.4	149.1
09/25/87	04:57:07	-53.3	26.9	76.5
09/25/87	04:57:10	-53.1	5.3	40.5
09/25/87	04:57:13	14.7	149.3	219.5
09/25/87	04:57:16	-51.2	122.1	219.5
09/25/87	04:57:19	176.3	205.1	219.5
09/25/87	04:57:22	-53.3	-8.0	14.9
09/25/87	04:57:25	-53.3	128.5	219.5
09/25/87	04:57:28	14.9	105.9	219.5
09/25/87	04:57:31	-53.1	122.7	219.5
09/25/87	04:57:34	217.5	219.5	219.5
09/25/87	04:57:37	-52.8	77.3	219.3
09/25/87	04:57:40	202.7	213.9	219.5
09/25/87	04:57:43	-53.1	128.5	219.5
09/25/87	04:57:46	74.4	171.2	219.5
09/25/87	04:57:49	111.7	183.5	219.5
09/25/87	04:57:52	-52.3	56.0	127.7
09/25/87	04:57:55	-53.1	37.7	219.5
09/25/87	04:57:58	-52.8	123.3	219.5
09/25/87	04:58:01	-51.5	49.6	219.5
09/25/87	04:58:04	-52.5	88.3	219.5
09/25/87	04:58:07	-53.1	100.3	219.5
09/25/87	04:58:10	82.9	154.7	219.5
09/25/87	04:58:13	219.3	219.5	219.5
09/25/87	04:58:16	-53.3	66.1	191.5
09/25/87	04:58:19	-53.1	108.5	219.5
09/25/87	04:58:22	-53.1	65.3	199.4
[illegible]	04:58:25	[illegible]	199.7	219.5
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

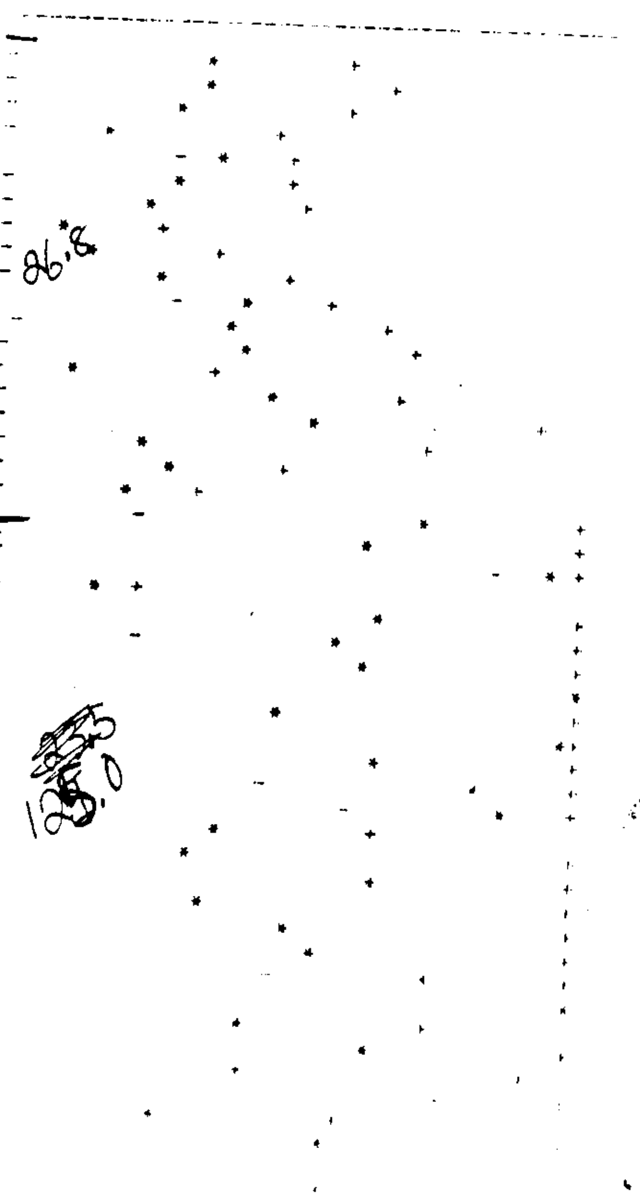


Exhibit 56. Fluid Recovery
Rates for the Framo Skimmer
from Tank Depth Measurements

Static Data Summary Sheet
Date: 24 September 1987
Time: 17:25 -- 17:44
Skimmer: FRAMO

Clock time (NLT)	Elapsed Time (min) Cumulative	Elapsed Time (min) Discrete	Height (Inch)	Volume (US gal)	Volume (cu m)	FFR (gpm) Cumulative	FFR (gpm) Discrete	FFR (cu m/hr) Cumulative	FFR (cu m/hr) Discrete
17.24	0.0 +/-0.00		3 +/- 1.0	68 +/- 37	0.3 +/- 0.1				
17.29	5.0 +/-0.17	5.0 +/-0.17	22 +/- 1.0	1262 +/- 81	4.8 +/- 0.3	252 +/- 25	239 +/- 31	57.3 +/- 5.6	54 +/- 7
17.34	10.0 +/-0.17	5.0 +/-0.33	28.5 +/- 1.0	1807 +/- 87	6.8 +/- 0.3	181 +/- 7	109 +/- 41	41.1 +/- 1.7	25 +/- 9
17.39	15.0 +/-0.17	5.0 +/-0.33	40.5 +/- 1.0	2885 +/- 92	10.9 +/- 0.3	192 +/- 4	216 +/- 50	43.7 +/- 0.9	49 +/- 11
17:42	18.0 +/-0.17	3.0 +/-0.33	42.5 +/- 1.0	3068 +/- 92	11.6 +/- 0.3	~~[illegible]~~ +/- 2	61 +/- 180	43.6 +/- 0.5	14 +/- 40
Stripped water			22.7 +/-1.00	1326 +/- 82	5.01 +/- 0.3	170			
Stripped oil			27.7 +/- 1.00	1742 +/- 100	6.62 +/- 0.4				

Exhibit 59. Fluid Recovery
Rates for the GT185 Skimmer
from Tank Depth Measurements.

Static Data Summary Sheet
Date: 24 September 1987
Time: 18:25 -- 18:56
Skimmer: GT185

Clock Time	Elapsed Time (min) Cumulative	Elapsed Time (min) Discrete	Height (Inch)	Volume (US gal)	Volume (cu m)	FFR (gpm) Cumulative	FFR (gpm) Discrete	FFR (cu m/hr) Cumulative	FFR (cu m/hr) Discrete
18:27	0.0 +/-0.00		0.5 +/- 1.00	5 +/- 20	0.02 +/- 0.07				
18:31	4.0 +/-0.17	4.0 +/-0.17	9.0 +/- 1.00	348 +/- 58	1.32 +/- 0.22				
18.36	9.0 +/-0.17	5.0 +/-0.33	17.0 +/- 1.00	875 +/- 74	3.31 +/- 0.28	86 +/-18	86 +/- 23	19.51 +/- 4.1	19.49 +/- 5.2
18.41	14.0 +/-0.17	5.0 +/-0.33	22.0 +/- 1.00	1262 +/- 81	4.78 +/- 0.31	87 +/- 6	105 +/- 34	21.98 +/- 1.5	23.95 +/- 7.6
18.46	19.0 +/-0.17	5.0 +/-0.33	26.0 +/- 1.00	1539 +/- 85	6.03 +/- 0.32	90 +/- 3	77 +/- 36	20.41 +/- 0.7	17.55 +/- 8.2
18.51	24.0 +/-0.17	5.0 +/-0.33	32.0 +/- 1.00	2115 +/- 89	8.00 +/- 0.34	84 +/- 2	66 +/- 38	18.99 +/- 0.4	15.03 +/- 8.6
18.56	29.0 +/-0.17	5.0 +/-0.33	36.0 +/- 1.00	2474 +/- 91	9.37 +/- 0.34	88 +/- 1	104 +/- 42	19.98 +/- 0.3	23.72 +/- 9.5
						85 +/- 1	72 +/- 42	19.36 +/- 0.2	16.34 +/- 9.3
Stripped water			0	0					
Stripped oil Emulsion			36.04 - 1.00	2474					

Exhibit 61. Results of Laboratory Analysis of In-Line Samples for Percent Water.

SKIMMER OR TANK	SAMPLE NO.	VOLUME (ml)	WATER CONTENT %	SPECIFIC GRAVITY	COMMENTS
FRAMO	1	143	94.0	Not Determined	
	2	160	84.4	Not Determined	"Duplicate" of 1
	3	175	93.7	Not Determined	
	4	158	82.9	Not Determined	Duplicate" of 3
	5	164	64.6	Not Determined	
	6	173	69.4	Not Determined	Duplicate" of 5
	7	156	97.4	Not Determined	
GT185	8	165	75.1	Not Determined	
	9	117	38.5	Not Determined	
	12	184	47.3	Not Determined	
	13	181	65.2	Not Determined	
	14	167	56.9	Not Determined	
	15	182	44.5	Not Determined	
HORS	19	116	64.6	Not Determined	Uncertain origin
TANK 1 (Starboard)	2	50	46.0	0.939	FRAMO Recovery Tank (After
	2A	50	48.0		Duplicate of 2
TANK 2 (Port)	3	50	26.0	0.946	GT185 Recovery Tank
	3A	50	27.0		Duplicate of 3
TNS STERN	1	50	0.0	0.822	Original Dumped Oil
	1A	50	0.0		Duplicate of 1

Exhibit 62. Results of Laboratory Analysis of Johnson Samples for Percent Water.

DEPTH INTERVAL (IN.)	SAMPLE VOLUME (ml)	WATER VOLUME (ml)	RELATIVE OIL (%)	VOLUME REPRESENTED (GALLONS)	OIL VOLUME (GALLONS)
----FRAMO SKIMMER----					
0-6	34 +/-1	17 +/- 2	50%+/- 7%	192 +/- 12	96 +/- 20
6-12	15 +/-1	5.5 +/- 1	63%+/- 9%	338 +/- 16	214 +/- 41
12-18	25 +/-1	10 +/- 2	60%+/-10%	420 +/- 19	252 +/- 52
18-24	19 +/-1	7.5 +/- 1	61%+/- 7%	475 +/- 21	288 +/- 47
24-30	7 +/-1	1.35 +/-0.5	81%+/-10%	151 +/- 21	122 +/- 32
TOTALS				1576 +/- 89	972 +/-192
RECOVERY EFFICIENCY			32%+/- 7%		
----GT185 SKIMMER----					
0-6	27 +/-1	19 +/- 2	30%+/-10%	192 +/- 12	57 +/- 23
6-12	24 +/-1	12 +/- 1	50%+/- 6%	338 +/- 16	169 +/- 29
12-18	27 +/-1	15 +/- 2	44%+/- 9%	420 +/- 19	187 +/- 48
18-24	29 +/-1	14 +/- 1	52%+/- 5%	475 +/- 21	246 +/- 35
24-30	25 +/-1	14.5 +/- 1	42%+/- 6%	513 +/- 22	215 +/- 42
30-36	19 +/-1	9 +/- 1	53%+/- 8%	384 +/- 23	202 +/- 42
TOTALS				2322 +/-112	1076 +/-218
RECOVERY EFFICIENCY			43%+/- 9%		

FIGURE 16

TEMPERATURE DURING EXERCISE